COMMON COMMODITIES OF COMMERCE

IRON

IRON AND STEEL

From a colour photo by Dr. H. G. Drake-Brockman, F.R.P.S.

Tapping a Blast Furnace at Clarence Iron Works.

PITMAN'S COMMON COMMODITIES OF COMMERCE

IRON AND STEEL

THEIR PRODUCTION AND MANUFACTURE

BY

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(Of the Firm of Messrs. Bell Brothers, Limited)

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INTRODUCTORY

Of all the Commodities of Commerce Iron is by far the most important. In this country it forms the basis of an Industry which ranks second only to that of Agriculture, it enters essentially into every other manufacture, it is the maid-of-all-work of Science, the servant of the Arts. The civilisation of nations is measured by it, wealth results from its possession and progress accompanies its use.

In writing the story of iron in the short space which this book necessarily allows, it is manifestly impossible to deal with finished manufactures save those which are made directly from the raw material such as rails, girders, bars, plates, etc., and even these can only be treated in a very general way. The endeavour of the Author has been to write of the subject on broad lines, and thus give a comprehensive and clear account of it without too much detail. He wishes to express his obligation to Scrivenor's *History of the Iron Trade*, Swank's *Iron in all Ages*, and Sir Lowthian Bell's work, *Principles of the Manufacture of Iron and Steel*, and to thank Mr. S. Marston, of the North Eastern Steel Co., and Mr. Henry Simpson, of the Middlesbrough Chamber of Commerce, for much valuable assistance.

" Gold is for the mistress—silver for the maid !
Copper for the craftsman cunning at his trade."
" Good ! " said the Baron, sitting in his hall,
" But Iron—Cold Iron—is master of them all ! "

From the Poem " Cold Iron " in *Rewards and Fairies*, by Rudyard Kipling. By permission of Messrs. Macmillan & Co.

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CHAPTER I

IRON ORES

To begin at the very beginning it is necessary to consider the origin of the iron which is found in the rocks, from which it is extracted by the ironmaster. It has been estimated that iron forms 5 per cent. of the total substance of the earth, but it is very unevenly distributed. It occurs from a minute trace up to 70 per cent. of the whole rock, but it is only with rock containing more than about 25 per cent. of iron that the ironmaster is concerned. How then did the iron get into the stone? It does not occur as pure metal but is combined with oxygen, carbon, sulphur, etc., and many theories have been formulated to account for its presence. One or two of these theories, which have met with more or less general acceptance, may be mentioned.

In many cases it is quite evident that the iron was not present when the rock, which now contains it, was first formed. This is the case with the Cleveland ironstone. In a paper read recently, Mr. J. E. Stead confirmed the opinion expressed by the late Dr. Sorby that the iron in this stone came there by replacement. Dr. Sorby's opinion was that the bed of iron-stone was originally a bed of impure limestone, that the iron was

carried down in solution by water highly impregnated with carbonic acid through the limestone when the limestone was dissolved by the carbonic acid and the iron left as a solid in its place. The reaction is most clearly expressed in its chemical formula thus:

$CaCo_3$	+	Fe_2CO_3	=	Fe_2CO_3	+	$CaCO_3$
Solid.		in Solution		Solid.		in Solution.

The impurities in the original limestone have, of course, remained, and therefore the ore is only of low grade.

In the case of the rich Hematite ores of Cumberland, Mr. J. D. Kendall's theory is that iron in solution, such as an aqueous solution of perchloride of iron, was forced up from the depths below and was caught up by the underground waters circulating among the rocks, thus coming in contact with the limestone. The reaction of the iron and lime took place causing the iron to be deposited and the lime carried away, carbonic acid being given off. The reaction is expressed in chemical formula thus: $Fe_2Cl_6 + 3CaCO_3 = Fe_2O_3 + 3 (Ca\,Cl_2 + CO_2)$. In this case the source of the iron is assumed to be volcanic, whereas in the case of the Cleveland iron-stone the iron is assumed to have been dissolved out of the superincumbent strata.

The huge masses of magnetic iron ore which are found in Scandinavia occur in primary rocks, and the conditions under which these rocks were formed are so problematical that any theories as to the origin of the magnetite can be little more than vague generalisations. In the welter of heat and motion, of dynamic force and of chemical and electrical action which the earth suffered when its surface passed from the liquid to the solid state, and the interior was still probably more or less gaseous, it may be that the iron was forced up in a gaseous or liquid condition into the rocks just

formed and there solidified into its present condition, though how the oxides of which the ore is composed were formed and separated so completely as they are from other substances it is hardly possible to make even a guess.

Passing from the question of the origin of iron ores to their practical use in making iron at the present time, their value in this regard depends on the quantity of iron they contain, the form in which that iron exists, the impurities associated with them, their mechanical condition and their accessibility. Ores with less than about 25 per cent. of iron, unless they contain a large percentage of lime, are hardly worth using, as the cost of smelting nearly four tons of stone to obtain one ton of iron is usually prohibitive.

The form in which the iron exists in the stone affects its value, because some compounds of iron are much more difficult to reduce than others. There are three compounds of oxygen and iron, viz., Ferric oxide (Fe_2O_3) Ferrous oxide ($Fe\ O$) and Magnetic oxide (Fe_3O_4). It is doubtful whether the latter is a separate compound or only a mixture in definite proportions of the other two. The ferric oxide is the most easily reducible compound, requiring less coke in the blast furnace than either of the others. Ferrous oxide comes next and the magnetic oxide, or magnetite last, as it is very dense and hard and requires great heat to smelt it.

The nature of the impurities in the gangue, or other matter associated with the iron in the ore, affects its value. Thus ores containing appreciable quantities of arsenic, chromium, titanium, lead, zinc, copper, etc., or excessive quantities of sulphur, silica, or alumina are much less valuable than ores without or with less of these substances because they either affect the fabric

of the furnace injuriously in smelting or require more fuel, or produce inferior iron.

The mechanical condition of ores also affects their value. The iron sand of New Zealand has been often tried, but the attempts to make iron from it have hitherto been unsuccessful. In recent years a large iron ore property in Spain was opened out, but when the ore was brought to market it was found to be so fine that it could not be smelted, and an expensive plant for making briquettes out of it had to be installed before it could be used.

That the accessibility of an ore qualifies its value hardly needs stating. The poor iron-stone of Cleveland, containing less than 30 per cent. of iron, because it is easily accessible and in close proximity to the Durham coal-field and a navigable river, has been the source of the most important iron trade of Great Britain, while the rich ores of Brazil, far from coal and difficult of access, still rest in their native beds.

Ore which, when mined, is unsuitable for any of the reasons given may sometimes be rendered suitable by preliminary treatment. Ore poor in iron may be crushed and washed, or electrically treated, so that its percentage of iron is largely increased. The great Dunderland Iron Ore Co. was formed so to "concentrate" an immense deposit of ore in Sweden which was otherwise of no value. Many other ore properties are at present being developed in a similar way and "concentrates" are becoming a regular article of commerce. Preliminary treatment may also modify the objection to Ferrous and Magnetic oxides. The hard dense magnetic ore of Sweden and Norway when broken into small pieces presents a much greater surface to the heat and is thus much more easily reduced than when charged in large lumps. The calcining of Cleveland and similar

stone, although that operation is usually regarded as part of the process of making iron is really a preliminary treatment of a poor ore by which the percentage of iron is largely increased and the form of it changed from Ferrous to Ferric oxide.

Ores may be classified according to the form in which the iron is found in them, that is, as Carbonate, or Ferric, Ferrous, or Magnetic oxide ores; or they may be described by the character of the "gangue" with which the iron is associated, that is, as Argillaceous, Silicious, Aluminous, Calcareous or Bituminous ores, but the simplest division of them, and the most useful generally is as phosphoric and non-phosphoric ores. A non-phosphoric ore is one which contains less than .03 per cent. of Phosphorus; all others are Phosphoric. This division arose when the Bessemer process of steel-making was first invented and it was found that iron containing more than ·05 to ·08 per cent. of Phosphorus was unsuitable for making steel by that process. A demand at once arose for ores low in phosphorus which had not up to then been regarded as especially valuable. The development of the acid processes of steel-making has maintained and extended that demand, and non-phosphoric ores have to-day a considerably higher value than the best phosphoric ores. Until the invention of the basic process Hematite iron made from non-phosphoric ores was the only material available for making steel in the Bessemer Converter or Siemens Furnace. It is probable that with the extension of the Basic process the relative values of phosphoric and non-phosphoric ores may be considerably altered in the future.

The principal non-phosphoric ores of Great Britain are the Hematite ores of Cumberland and North Lancashire. Less important are the brown Hematite in

the Forest of Dean and in Antrim. The most important deposits of this ore in Europe are those of Spain. As there is no coal available for smelting them there they are exported to Great Britain and Germany and provide the principal material for the Hematite iron trade of the North East of England, the West of Scotland, South Wales, and in a considerable degree of the Westphalian district of Germany. In the United States the Lake Superior district supplies the principal non-phosphoric ores. The enormous supply of this ore and its excellent quality account largely for the enormous development of the American iron and steel trades. The ore is found in five ranges on Lake Superior, viz., Marquette, Menominee, Gogebic, Vermilion and Mesaba. The largest quantity is now worked from the Mesaba range though it was the last opened. The quantities worked in 1901 were

Marquette . .	3,254,680	tons
Menominee . .	3,605,449	,,
Gogebic . .	2,938,155	,,
Vermilion . .	1,786,063	,,
Mesaba . .	9,001,890	,,

In 1906 the total output was estimated at 49,670,000 tons.

The ore varies in percentage of iron from 54 to 68, is low in Silica, Phosphorus and Sulphur. The Mesaba ore is very fine mechanically, and the furnaces using it have to be built on special lines.

Of phosphoric ores there is a very large supply. In Great Britain the Blackband iron-stone of the coal measures, now almost exhausted, was the foundation of the iron trade of Scotland. The Cleveland iron trade has been built up on the ironstone of the district. Lincolnshire, Northamptonshire and Rutland have large deposits which are being extensively worked, and Wales, both North and South, possesses considerable

supplies. The iron trade of Staffordshire has been maintained for more than a century principally on the local iron-stone of the coal measures, though of late years large quantities from Northamptonshire and other districts have had to be imported. On the Continent the most important among many large deposits is the Minette ore of Luxemburg and Elsass-Lothringen. Upon this Germany has built up an immense iron trade, and it is also the source of most of the iron manufacture of France and Belgium. The exploration of these huge deposits is still going on, and proposals for supplying the ore to English works have been made from time to time. Austria has large deposits in Styria. Spain, Greece and Russia have large quantities available. The Magnetic ores of Scandinavia have been largely drawn upon by Germany and Great Britain. In America the largest deposits being worked are the Wabana ore of Bell Island, Newfoundland, and the Alabama ore of the Southern States.

A recent investigation shows that the iron ore resources of the world are practically inexhaustible. In some countries, such as Russia and China, there are immense fields which have never been thoroughly investigated. The mineral resources of China in particular are known to be very large. It is said that a mining engineer who was sent to Manchuria to report on a coal-field there returned in despair because he found a seam of coal eighty feet thick which he could not imagine how to work. It is more than probable that China with her great natural wealth of coal and iron ore, her cheap labour, and the intelligence of her people will become one of the great industrial nations, competing successfully with Europe and America in the world's markets.

The pig iron which is produced from native ore in

Great Britain is made chiefly in Cleveland and Durham, the Midland Counties and Staffordshire, Cumberland and North Lancashire, and Lincolnshire, from the Cleveland, the Northampton and the Lincolnshire ironstone and Cumberland ore. The Cleveland iron-stone is a carbonate of iron found in the Lias, which has to be calcined before going into the furnace. It is mined, and the output in 1909 was 6,191,172 tons. The Northampton stone is a brown ore from the Oolite, which is quarried in Northants and Rutland. The Cumberland ore is Hematite of great purity. The Clayband iron-stone of Wales, Staffordshire, and Shropshire is next in importance to those mentioned. The total quantity of iron ore raised in Great Britain in 1909 was 14,979,979 tons.

Typical analyses of English ores are given below.

	Cleveland (as mined)	Northants (as mined)	Lincoln (dry)	Cumberland (dry)
	%	%	%	%
Ferrous oxide	34·80	1·78	2·31	—
Ferric ,,	1·01	48·88	30·28	84·41
Manganous ,,	·43	·20	·40	·32
Alumina	12·90	6·66	5·11	·97
Lime	5·83	2·15	24·12	·706
Magnesia	3·42	·81	·86	·11
Silica	13·40	7·89	8·25	7·36
Phosphoric Acid	1·15	·89	·35	·03
Sulphur	·16	·12	·02	·004
Carb. Acid, etc.	20·70	12·37	28·30	1·09
Combined Water	1·20			5·00
Moisture	5·00	18·34		
Metallic Iron	27·79	35·60	23·00	59·08
Iron in Calcined Stone	37·66			

Since this book was begun an important discovery of ore in the Isle of Raasay on the West Coast of Scotland has been announced. This ore is in a bed which ranges from six to seventeen feet in thickness, and is in the same geological horizon as the Cleveland Iron-stone, viz.,

about the junction of the middle and upper Lias, and is apparently of the same character as that stone. The following is said to be a typical analysis of this ore:

Ferrous oxide	30·3	Carbon dioxide	28·3
Ferric ,,	2·3	Silica	6·5
Manganous ,,	·4	Sulphur	·2
Alumina	5·6	Phosphoric Acid	2·3
Lime	17·6	Water, etc.	4·5
Magnesia	2·0		

From this it will be seen that although it is lower in the iron it contains than Cleveland stone it has much less silica and much more lime, two very important and valuable advantages. Its higher Phosphorus makes it an ideal ore for the manufacture of basic iron for steel-making, and, if the present reports of it are confirmed on further development of the seam, a very valuable addition to the iron ore resources of Scotland has been made. The Island of Raasay is said to have been purchased by Messrs. William Baird & Co., Ltd., the great Scotch ironmasters.

CHAPTER II

COKE AND LIMESTONE

NEXT to the ore the most important material required in making iron is fuel. This in the blast furnace takes the form of Coal and Coke. In the Scotch furnaces coal is used, and the by-products of the distillation of it in the furnace are collected from the gases. In America Anthracite Coal is used, where that is mined, but coke is the fuel which is generally used in most iron districts. The weight of the "burden" in modern furnaces would crush ordinary coal so small that the passage of the blast would be seriously obstructed, and the hard coke of Durham therefore forms the most satisfactory fuel in the blast furnace. The quality of coke depends on its hardness physically, and chemically upon the percentage of fixed carbon, sulphur and ash. Sulphur is one of the great enemies of the ironmaster and ash is a useless material. The best Durham coke was made from the Brockwell seam of coal, but that is now nearly all worked out. All coke was at one time made in Beehive ovens by which all the by-products of the distillation were lost, passing off into the flues and thence into the air. This process, however, is said to have produced the hardest coke.

The new regenerative by-product coke-ovens have of late years been installed, and where practicable are put down near to the furnaces instead of at the collieries, so that the gases may be available for power purposes, and this system has the further advantage of saving the handling and consequent breakage of the coke, and minimising the opportunities of its absorbing moisture

in transit. The recovery of the by-products more than compensates for the increased first cost of the ovens and the extra cost of renewals and repairs. The by-products recovered are

TAR, from which Pitch is sometimes extracted.

LIQUOR, from which Sulphate or other Ammonia Salts are recovered.

LIGHT OIL or CRUDE BENZOLS, or similar bodies, from which occasionally purer Benzols, Solvent Naptha, Toluene, Xylene, Napthalene, etc., are prepared.

In a few cases the gases are also further treated to extract Ferro-Cyanides or other Cyanide compounds. These by-products now form the basis of a great industry which is increasing year by year. Large quantities of Sulphate of Ammonia and Benzol, as well as Pitch, are exported to various parts of the Continent and to Japan.

The average composition of a good present-day Durham coke, which may be regarded as a standard, would be

Ash	8 to 10%
Sulphur	1 to 1·3%
Volatile Hydro Carbons	from Trace to 1%
Moisture	from Trace to 2%
Balance being fixed Carbon	

The establishment of an iron industry depends more upon the presence of an ample supply of fuel than of iron ore. Thus we see that neither Spain nor the Scandinavian countries have been able to undertake the manufacture of iron to any serious extent, whereas the iron trade of South Wales is carried on now very largely by means of imported ore, which is smelted with the local coke.

In order to carry off the impurities in the ore it is necessary, as a rule, to add a flux to the charge which

helps to form a slag. In the case of ore containing a considerable quantity of lime this is not necessary.

Limestone is the flux most generally used, and in modern practice in Cleveland it is usual to pass it through the kilns with the iron-stone, by which means it becomes intimately mixed with the iron-stone, and is converted into lime.

A fairly representative analysis of a suitable limestone for use as a flux would be

Silica	·5% to 2%
Iron Oxides and Alumina from	1% to 2%
Carbonate of Magnesia	from 1·5% to 3%
Balance is Carbonate of Lime.	

THE HISTORY OF IRON-MAKING

CHAPTER III

ORIGINS AND PROGRESS

THE beginning of the story of the making of iron is lost in the dim mists of forgotten ages. It may be that, as in the case of copper, the first man who used iron beat it out in the ore, but it is more likely that a piece of rich ore was accidentally heated in a fire and malleable iron produced. What a prize the first piece would be to the owner of it, how it would be hammered and tested and tried and compared with copper and bronze, for there is not much doubt that copper and tin were the first metals used. How far back in the history of man this discovery was made it is impossible to say, but in the time of Homer the manufacture of iron was well known, and the Egyptians made and used it at an early period in their history.

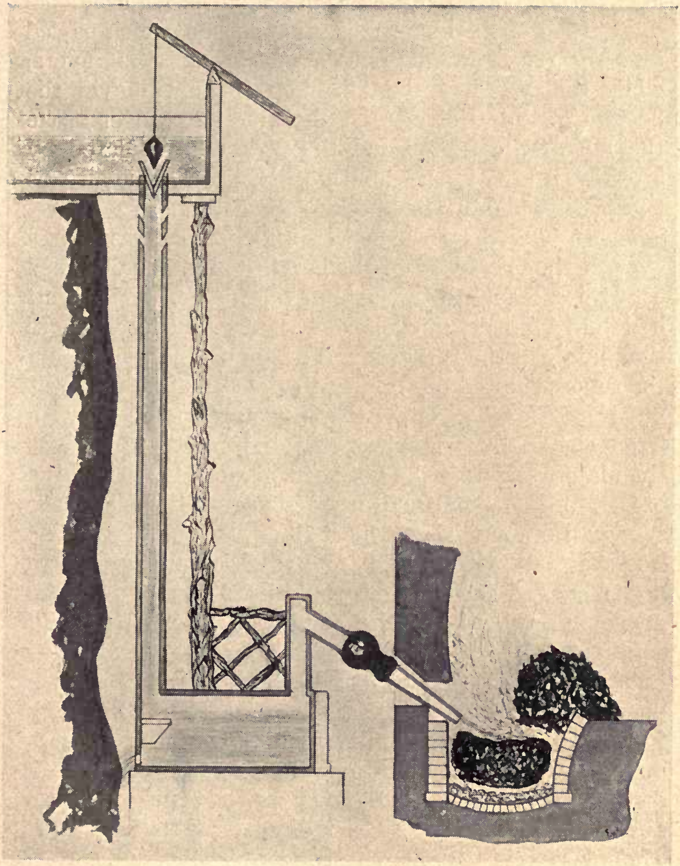
After the first discovery of the metal it would not be long before its manufacture became an ordinary and well-known operation, the ore probably being at first simply heated in a fire and afterwards the intensity of the heat being increased by blowing, at first through a tube with the mouth and later by bellows. It is interesting to know that notwithstanding all the progress which has been made since the men of the stone age lived and fought their way upward, this primitive method of making iron is still—or was until recently—used in Central Africa and also in that land of changeless life, India. There the "ironmaster" with his few pieces of iron ore and charcoal squats down, sets the charcoal alight and blows through his bamboo cane

until the ore is reduced and a few pounds of iron produced, which he at once proceeds to dispose of. It has been calculated that a modern blast furnace will produce as much iron in a day as would be made by 100,000 men in the same time by this method.

For thousands of years this was the only method of making iron, the only progress during that long period being in the improvement of the apparatus used. The simple heap of ore and charcoal producing a few pounds of iron gave place to the Catalan forge of the Pyrenees, the Stückofen of Germany, and the Osmund furnace of Sweden yielding two or three tons per week of malleable iron. Traces of the use in England of this method still exist in the heaps of scoriæ resulting from the manufacture, which are found in the Cleveland hills, the Forest of Dean, Cumberland, Sussex, and other places.

The great importance of the Catalan forge as the only instrument for the manufacture of iron over a long period, and one which has survived to our own time, justifies a detailed description of the furnace and its use.

The furnace, which is shown on p. 15, consisted of a rectangular hearth about 3 ft. by 2 ft. 6 in., tapering to 2 ft. 2 in. at the bottom. The hearth was built of refractory bricks set in fire-clay. The bottom was supported on arches, and on these was a layer of fireclay and slag well beaten down. Above this was the bottom made of sandstone or granite. The side walls were heavy iron bars laid on one another, the back wall was brick and the front wall was two iron plates, in the lower one of which was a hole for tapping out the slag. The tuyere was of copper and inclined 30° to 40° to the horizontal. The blast was supplied by a trompe, or water-blower, as shown in the illustration. The



CATALAN FORGE

water reservoir was connected to the receiver by a pipe about 20 ft. long. The water in falling through the pipe drew air through the apertures in the side, which passed into the receiver and was forced through the tuyere, while the water escaped through the opening in the bottom of the receiver. A shelf in the receiver broke the fall of the water, and the flow was regulated by inserting a plug in the mouth of the pipe. The air was necessarily highly charged with moisture.

In working the furnace, burning charcoal was spread over the hot bottom and the hearth was gradually filled up with charcoal to the level of the tuyere. When this had burnt up an iron sheet was put vertically across the middle of the furnace, and on the farthest side from the tuyere roasted ore broken to the size of an egg, was put in. The side nearest the tuyere was filled up with large charcoal. The blast was then put on, and as the plate was raised the hot reducing gases acted on the ore. More charcoal and ore were then added and the spongy iron and slag collected on the bottom. The slag was tapped off from time to time, and after five or six hours sufficient iron would have formed to make a bloom, which was then removed, hammered and squeezed to get rid of slag and shaped to bars. From half a ton of ore, about 3 cwts. of iron would be produced by using 11 cwts. of charcoal. The Bloomery furnace worked in a similar manner, but the ore was used in a finer condition and the furnace was worked continuously. The High Bloomery, or Stückofen, was about 15 ft. high and 3 ft. diameter at the hearth. The blast was supplied by bellows driven by a water-wheel, and the lump of iron was withdrawn through the tuyere arch, the slag being run from a separate tap-hole.

The first great step towards modern methods of iron-making was taken when cast-iron was first produced.

Although this only took place some 400 to 500 years ago nothing is known about its discovery. It seems most probable that this came about through the use of bigger furnaces and greater heat for reducing ores by which the iron became fused and took up a portion of carbon from the fuel. It is known that in Germany, in the sixteenth century, antimony and other metals were added to the charge of ore to reduce the melting point of the iron and enable cannon to be made of the metal. The first cannon of cast-iron was made in England at Buxted, in Sussex, by Ralph Hogein in 1543, and ordinary iron castings were made first in 1706 by Dutch workmen imported to make brass. From this it would appear that the art of casting in metals was known better on the Continent at that time than in England. It is evident from these dates that the uses to which the metal in its new form could be applied were not at once discovered. The cast-iron first produced would be of low quality unsuitable for making good castings, and it would no doubt be reheated and converted into malleable iron. The Catalan forge and the Stückofen gradually gave place to the blast furnace, the greater economy of fuel, the larger output and the new uses to which the cast-iron could be put more than compensating for the substitution of a single process by a double one, in the manufacture of malleable iron. Many efforts have since been made to produce malleable iron by a single process direct from the ore, but not one has succeeded in competing with the blast furnace and puddling furnace, the reasons for the failure being that the blast furnace extracts practically all the iron from the ore at a small expenditure of fuel, whereas the low temperature necessary in a direct process is wasteful in fuel and fails to extract a large percentage of the iron in the ore.

The next improvement in the process of iron-making was the substitution of pit coal for charcoal in the blast furnace. This was first attempted by Dud Dudley in 1618, but it was not until about 1733 that Abraham Darby succeeded in using coke in his blast furnaces.

Although it has no connection with the sequence of events by which the iron trade was developed, mention must here be made of the invention, in 1770, of cast steel by Huntsman of Sheffield, which will be referred to later on.

The next great step forward was the invention about the year 1784, by Henry Cort, of the puddling furnace and the rolling mill. Until then malleable iron had been made either by the direct process or from pig iron by reheating in the Catalan forge, or similar apparatus. Cort substituted a reverberatory furnace for the hearth of the forge, and grooved rolls for the forge hammer. The reverberatory furnace reduced the cost of manufacture and gave a larger output of a more uniform quality. S. B. Rogers greatly improved this furnace in 1816 by substituting an iron bottom for the sand bottom Cort employed. The forge hammer was only able to manipulate small blooms, and could fashion them only into shapes of very limited size and area. Cort's invention of grooved rolls, through which the iron was passed, enabled greater lengths and different shapes of rail or bar, and more varied and more regular thicknesses and sizes of plates to be made. Although Cort is credited with the invention of the rolling-mill, and was undoubtedly the first person to make extensive use of it, there is much evidence that both flat and grooved rolls were used before his time. Scrivenor, in his *History of the Iron Trade*, quoting from Coxe's *Tour in Monmouthshire*, says that John Hanbury invented the method of rolling iron plates by means of cylinders in the early part of

the eighteenth century. In Dr. Ure's *Dictionary of the Arts* the invention of flat or sheet rolls for rolling plates is attributed to John Payne. Mr. Swank, in his book *Iron in all Ages*, quotes patents for rolls of various forms for rolling bar iron, one being taken out in 1759 by Thomas Blockley. Cort, therefore, probably perfected the ideas of previous inventors and made a rolling-mill which was a success. An earlier invention than the rolling-mill was the slitting or splitting-mill, by which bars were cut into sizes for nail rods. This mill was invented in Sweden, and Scrivenor quotes from the *Letters of S. T. Coleridge* an extraordinary account of how the invention was brought to England by a man named Foley, living near Stourbridge. Foley was a fiddler, and in watching the process of nail-making noticed the labour and time taken up by dividing the iron rods. The invention of the slitting mill in Sweden greatly affected the nail trade in Stourbridge, and Foley disappeared and only returned after some years. He had resolved to find out the process of splitting the bars by machinery, and without a word to anyone he took his fiddle, went to Hull and worked his passage to the Swedish iron port. From there he fiddled and begged his way to the works where he ultimately became a great favourite of the workmen and was allowed to enter any part of the works. He learnt all he could, and then disappeared, returning to England. He consulted a Mr. Knight and another person and told them what he had learnt. The necessary machinery was erected by these people, but it would not do the work. Foley disappeared again, returned to Sweden, was received with joy by the workmen who lodged him in, of all places, the slitting mill itself. He discovered the cause of the failure at Stourbridge, made drawings and waited to verify his notes and then disappeared

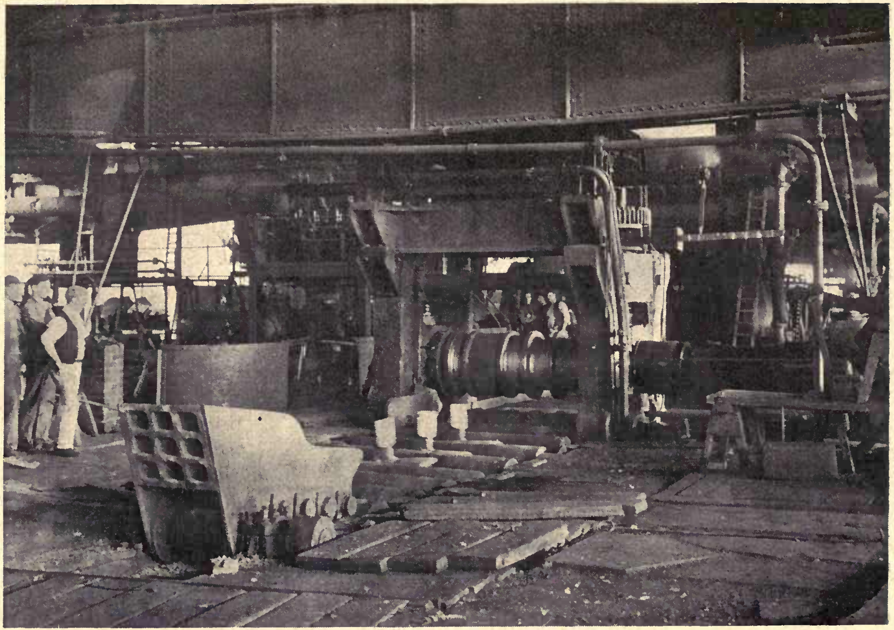
once more, returned to England and set the machinery to work, this time with success.

The two inventions of Cort marked the beginning of the modern treatment of iron and were the first step in the marvellous development of the use of iron which has taken place in our time. In the thousand years or so before Cort, in which the manufacture of iron was carried on in Great Britain the quantity made had reached about 100,000 tons a year. A hundred and twenty years later that quantity had increased to ten million tons.

The next great invention affecting iron manufacture was that of a Scotsman, James Beaumont Neilson, who, in 1828, conceived the idea of heating the air of the blast before forcing it into the blast furnace. This resulted in a great saving of fuel and a large increase in the output of the furnace.

At first the air was heated by passing it through an iron box heated by a fire, but inventors then set to work to find a means of saving the fuel required, the result being that about 1836 methods were devised for utilising the waste gas of the blast furnace itself by burning it in various forms of stoves, and then passing the air through the stoves in contact with the heated surfaces. Amongst the earliest of the stoves was one by Ford consisting of cast iron pipes, ∩ shaped, through which the air was passed, whilst the gases were being burnt about the outside of the pipes. By these stoves the air could be heated to about 570°F. Then came the Whitwell Stoves, consisting of chambers enclosing walls built of fire-bricks, and finally, about 1860, Mr. E. A. Cowper brought out his great invention of a regenerative stove with checker work lining of fire-brick in which the air can be heated to 1,600°F.

Neilson's great discovery is the more astonishing



COGGING INGOTS AT THE NORTH EASTERN STEEL WORKS

because there does not appear to have been any reason at the time for supposing that the heating of the blast would result in any economy in reducing the fuel used in the furnace, and at first the results of using hot blast created much astonishment and discussion. It was not until many years afterwards that the action of the hot blast in the furnace was thoroughly understood.

The blast furnace gases were in the meantime being used for raising steam for the blowing engines and auxiliary machinery about the furnace plant, but thinkers were busily at work on the problem of how to substitute another method of obtaining power for the wasteful steam engine. B. H. Thwaite was one of the first to propose the use of blast furnace gas direct in internal combustion engines, and during the past ten years the developments in this direction have been enormous. In modern works, the blast furnace gases not only supply power for their own requirements, but if the gases are used in gas engines in cases where steel works are run in conjunction with ironworks, the latter will supply the whole of the power required for the working up into finished steel of the whole of the iron output of the furnaces.

This complete utilisation of blast furnace gases is therefore an enormous economy, but it has the further most important advantage of conserving the coal supply of the world.

The utilisation of the furnace gas was the last of the great improvements in the manufacture of pig iron in the blast furnace. All subsequent progress in that manufacture has been made by improvements in apparatus and methods such as more powerful blowing engines giving a greater pressure of blast, the charging of the furnaces by mechanical means, etc., etc.

There remains to be dealt with the great discoveries and inventions affecting the treatment of the raw iron after it has left the blast furnace. These are the Bessemer process of steel-making, acid and basic, the Siemens-Martin open hearth process of steel-making, also acid and basic, and the electric furnace.

THE HISTORY OF MODERN STEEL PROCESSES

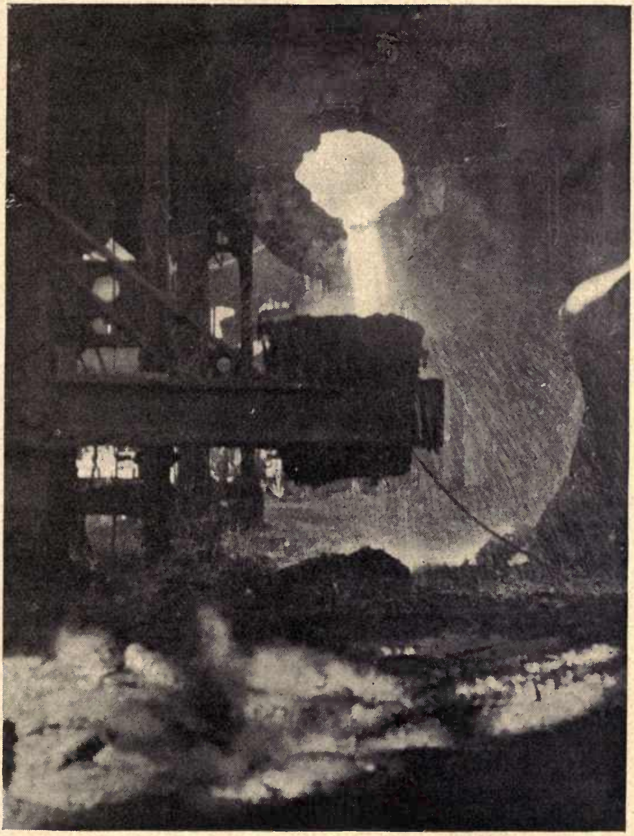
CHAPTER IV

THE BESSEMER PROCESS

In order to explain Henry Bessemer's great invention and the revolution which it brought about, it is necessary to refer to the position of the manufacture of iron and that of steel immediately before its discovery.

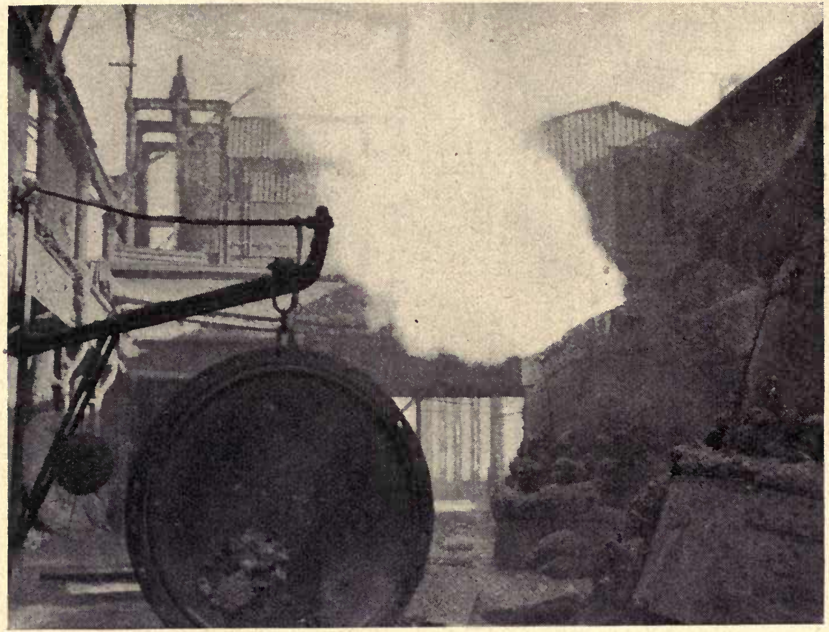
In 1855, when Bessemer's first patent was taken out, there was a clear distinction between iron and steel. Iron was made in the blast furnace and remelted in the cupola for castings, or treated in the puddling furnace, the forge and the mill for making rails, bars, plates, and all kinds of malleable iron products. Steel was made by the Cementation process, bars of very pure iron being impregnated with carbon by heating in charcoal. Steel was iron of great purity containing from half per cent. to 2 per cent. of carbon, which would harden when heated and quenched. Since Bessemer's invention the name of steel has been given to the product of the converter and the open hearth furnace ; it may contain any degree of carbon and does not necessarily harden after being heated and quenched.

Bessemer's discovery arose out of his endeavour to find a stronger material than cast-iron for making cannon. He wanted a material as hard and rigid as cast-iron and as tough as malleable iron. But the quantity of heat requisite for melting malleable iron is so great that up to his time it had been found impossible to liquify more than a few pounds at a time. Now the



TEEMING STEEL FROM BESSEMER CONVERTER TO
TRANSFER LADLE AT NORTH EASTERN
STEEL WORKS

difference between the composition of cast-iron and that of malleable iron is that the former contains much more carbon, silicon, phosphorus and manganese than the latter, and it is the elimination of the excess of these substances from cast-iron which converts it into malleable iron. In the puddling furnace this is done slowly by oxidation, but Bessemer conceived the idea of doing it rapidly by blowing air into or through the molten pig iron, and causing rapid oxidation of the metalloids. He succeeded in producing malleable iron in this way, but it was soon found that although sufficient of the carbon, silicon and manganese was removed the greater portion of the phosphorus was left in the iron and rendered it practically valueless. This difficulty, which could not be overcome, confined the process to iron containing very small quantities of phosphorus. No such iron had hitherto been made, but by using the pure ores of Cumberland and North Lancashire and by importing similar ores from Bilbao an iron was produced from which steel was made by blowing air through it in a molten state. But this was not what Bessemer set out to do which was to produce an iron low in carbon. The article he had produced was steel with ·5 per cent. or more of carbon, and when he tried to remove this carbon he found that he got some of the iron oxidized, which spoilt the metal. There is not much doubt that if the process had stopped at this point Bessemer's great invention would have been almost a failure, but at this juncture R. F. Mushet seeing that as it stood the process could not succeed, tried the use of Manganese in the form of Spiegeleisen after all the carbon was burnt out for the purpose of recarbonising the charge. This succeeded, and the result was that, by the use of Spiegeleisen and subsequently of ferro-manganese, steel was obtained containing any required



BESSEMER CONVERTER "BLOWING"—THE NORTH EASTERN STEEL WORKS

percentage of carbon. The product was called mild or soft steel because it was impossible to describe one cast as steel and another as iron from the same furnace when the only difference between them was a fraction of one per cent. of carbon.

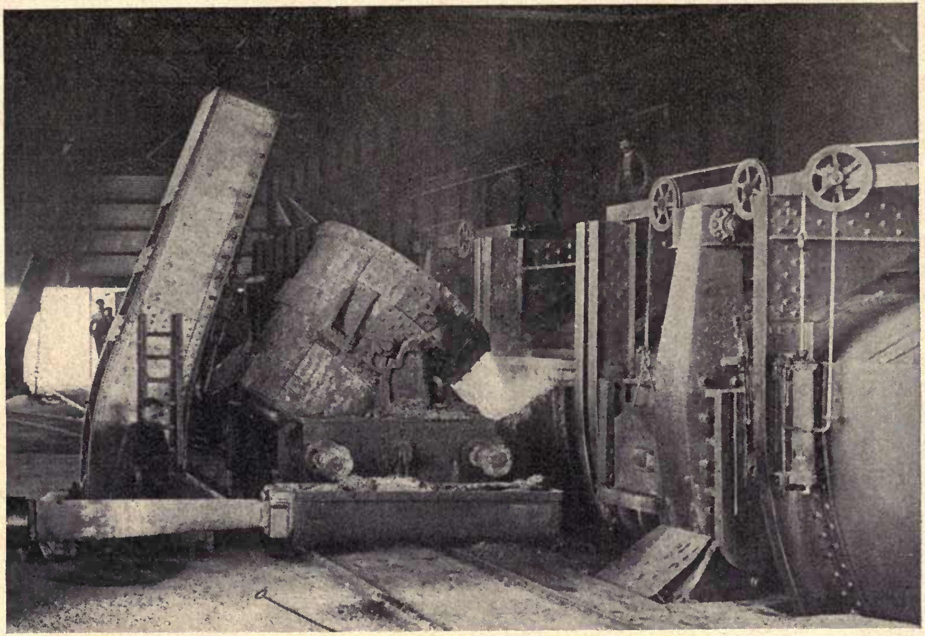
The object which Bessemer had set out to attain was now by the aid of Mushet's patent completely accomplished, and the result was a great change in the manufacture of iron and steel. The product of the Bessemer converter was of so much better quality, stronger, more homogeneous, more uniform and quite free from slag, and was also obtained at a less cost in less time and in larger quantity than the product of the puddling furnace that it quickly superseded the latter in all the heavy trades. First the rail trade, then the plate trade for shipbuilding and boilers, and the bar, angle and girder trades succumbed to the new process, and the manufacture of malleable iron declined to the humble position which it now occupies. It has been pointed out that the essential feature of Bessemer's great invention is the burning of the impurities out of the iron used, by blowing cold air through it whilst it is in a molten state. Although at first sight it appears anomalous that blowing cold air into red-hot metal should make that metal considerably hotter, viz., white hot, it will be seen on consideration to be quite simple because the combustion takes place inside the mass itself, and therefore the heat developed acts directly on it.

The impurities burnt out are silicon, carbon, manganese, and a small portion of the iron itself. The temperature of the molten iron may be taken at 1,200 to 1,400°C. and of the blown metal at 1,900 to 2,000°C.

With the introduction of the new process came an enormous development of new plant, calling for the

BESSEMER CONVERTER. FINISH OF "BLOW"—
NORTH EASTERN STEEL WORKS

highest skill of the engineer for its design and manufacture. To mention the plant as nearly as possible in the order of its use in the process, we have the cupolas, converters, casting crane, ingot crane, hydraulic pumps and blowing engines. The cupolas were required for melting the various selected pig irons to form the charge. This was run down spouts into the converter, which at first was a fixed vessel not unlike the cupola itself. The tuyeres through which the air was to be introduced into the bath of molten iron were placed round the sides near the bottom, but this converter was soon replaced by a tilting one. This type had many and obvious advantages, as it was easy to put into it the charge of iron and to take out the charge of finished steel. Also there were no troublesome tapping-holes requiring to be opened and closed every cast, that is about every half-hour. Another important point was that the air blown in at the sides only reached the portions of the metal adjacent thereto, and it was found necessary in order to reach the whole mass to blow right through the bottom. This involved changing the whole of the bottom every time the tuyeres were worn out, and led to the bottom section of the converter being made loose. Tilting considerably expedited the process of changing. Other and equally important advantages were derived from tilting, perhaps the most important being that the metal could lie in the belly of the converter and the iron be kept quite clear of the tuyere holes, until everything was ready to commence the blow. Then the blast was turned on and the vessel slowly rotated to a vertical position, thus bringing the bath over the tuyeres and the air penetrating through the whole body of iron. If anything went wrong, by turning the vessel down again the operation could with perfect ease be arrested, and resumed again at the will of the "Blower." As a

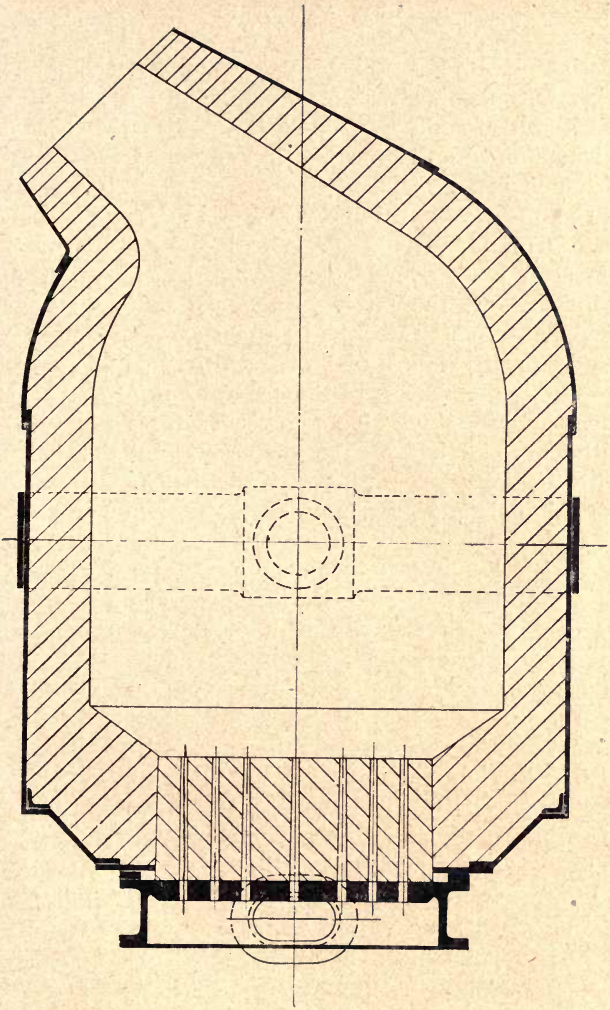


POURING MOLTEN IRON FROM LADLE INTO THE METAL MIXER AT NORTH EASTERN STEEL WORKS

five ton converter, when lined and charged, weighed some fifty tons it was necessary to provide powerful machinery to tilt it and the most satisfactory means was found in the use of a rack and pinion actuated by hydraulic pressure. Powerful centre cranes for carrying the ladles into which the finished steel was poured from the converter, and ingot cranes for fixing the ingot moulds around the semicircular casting pit then usually adopted, and for removing the ingots when cast were also actuated hydraulically. Last but not least entirely new conditions were imposed on the blowing engines, which were now required to work at a pressure of twenty-five to twenty-eight pounds for the Bessemer instead of five pounds for the blast furnace practice. Thus an enormous field of work was opened up for engineers in providing entirely new types of machinery for the new process, and in the enlarging and strengthening of the rolling-mill plants to deal with larger units of metal much harder to roll, and in vastly greater quantities than had previously been required. In those days the iron, to form the charge in the converter, had to be melted from pig iron, and both cupolas and converters required a lining of gannister in lumps with ground gannister as a mortar for the joints, and for lining the ladles. This opened out a period of prosperity for land and quarry-owners having suitable stone for the purpose, and it may be of interest to add that no better gannister has been found for the purpose than that in the neighbourhood of Sheffield where Bessemer built his first works.

Many other departments of industry were directly and beneficially affected, but sufficient has been said to indicate the wide-spreading results of Bessemer's epoch-making invention.

When the Basic Bessemer process came in, other



BESSEMER CONVERTER

special plant for burning the dolomite, crushers and mills for crushing and grinding it into a stiff paste mixed with tar, hydraulic presses for forming this into bricks and various other machinery called for the skill of the engineer.

The most recent improvements in Bessemer plant may here be referred to. The lower portion of the converter is now made more cylindrical and the bath more shallow, the latter being only 18 to 20 inches deep, as compared with 28 to 30 inches formerly. This requires less pressure of blast and the loss of metal is reduced. The bottom of the converter is now 70 inches wide, and the tuyeres are increased from 100 to 127 without reduction of the diameter. In the newest form at the Jünckerather Gewerkschaft, in Germany, the height is $22\frac{1}{2}$ feet, internal diameter at wind chest $7\frac{1}{2}$ feet, maximum diameter $10\frac{1}{4}$ feet, weight 70 tons, and with lining 180 tons, charge 30 tons. The old mixers of 150 tons capacity are replaced by mixers of up to 750 tons capacity with cylindrical rollers and operated by electricity. The iron is hauled by electric locomotives from the blast furnace to the mixer and from the mixer to the steel furnace, a tilting motor being carried on the same truck. Increased output is made possible by the greater durability of the linings, especially of the loose bottoms which now average a life of 280 charges, whereas needle bottoms only last sixty to sixty-five charges and tuyere bottoms ninety-five charges.

Bessemer did not, however, succeed in making steel in the converter from pig iron containing phosphorus, and as the demand for mild steel grew it became clear that the manufacture was limited by the supply of non-phosphoric ores. Few of the ores of Great Britain and only a small proportion of those of the world are non-phosphoric, and the great problem of how to use

the process for making steel from phosphoric ores was attacked by the greatest minds interested in the iron trade in Europe and America. Mr. G. J. Snelus discovered that if the converter were lined with a basic material such as lime the phosphorus was removed, but he failed to carry his ideas into practice. The solution came from a most unexpected quarter. Mr. Sidney Gilchrist Thomas, Clerk to the Magistrate at the Thames Police Court, took up the study of chemistry as a hobby, and at one of the evening classes which he attended the teacher referred to the problem which was exercising the brains of the ironmasters of the world. Mr. Thomas determined to try and solve it. He made many experiments in which he was aided by his cousin, Mr. P. C. Gilchrist, who was a chemist at the Blaenavon works in South Wales, and the result of their labours was laid before the Iron and Steel Institute in a paper read in 1878. The difficulty they had to overcome was how to make a lining of basic material for the converter which would stand. Snelus had tried lime and magnesia with clay and oxide of iron and had failed. They succeeded by using dolomite, first in blocks and subsequently burnt in bricks, with clay to give adhesion. When the lining was tried in a five-ton converter at the works of Messrs. Bolckow Vaughan & Co., at Middlesbrough, the charge was blown until all the carbon had gone, when it was found that dephosphorisation was not complete. Mr. J. E. Stead suggested "after-blowing," that is, continuing the blowing after the carbon had gone. After some hesitation, because an explosion was feared, the blowing was continued with complete success. Thus was the Bessemer process of steel-making completed by a student of chemistry, who had no practical experience whatever of the making of iron. The story is one of the romances of the iron trade.

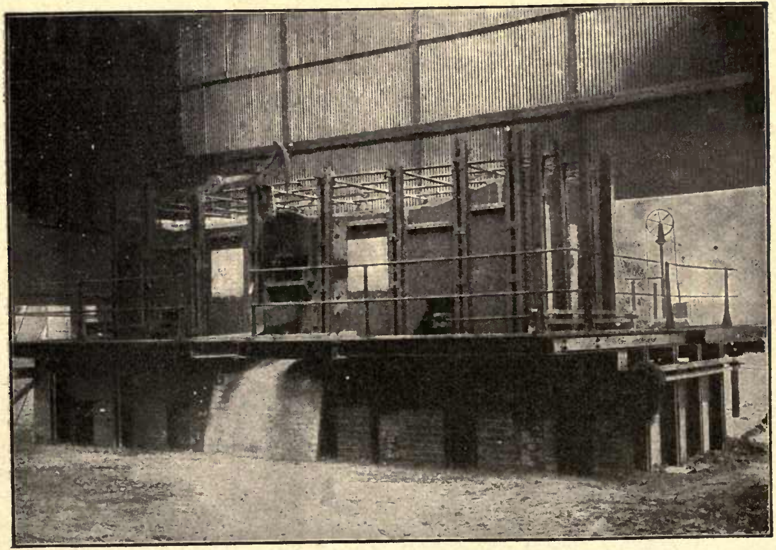
A recent writer intimately associated with the transition period from iron to steel has stated that the substitution of the Bessemer process for refining pig iron had resulted in a saving of 60 per cent. in the cost, and what was equally important it had made 100 tons of coal go as far as 400 tons did in the days of puddling.

The Bessemer process has seen its best days. Before many years are over it will probably be regarded as an old-fashioned and inefficient method, if it be not quite obsolete, but it can never be forgotten as one of the great discoveries in iron-making, marking the passing of the age of iron and the inauguration of that of steel.

CHAPTER V

THE SIEMENS-MARTIN OPEN HEARTH PROCESS

WHILE the Bessemer process was being perfected, another process which has already largely superseded it and will probably in the end quite prevail, was being discovered. In 1827 Robert Stirling invented an apparatus in connection with heat engines for storing and restoring heat. It was simply a passage through which air or gas could travel in either direction, the walls of which had a great capacity for heat, so that heat could be alternatively given to or taken from them by the air or gas passing through. In 1856 Friedrich Siemens applied this principle to a furnace. The hot gases from the furnace were passed through a regenerator in the form of a chamber stacked with loose bricks, which absorbed the heat, and when the bricks were hot the gases were turned off into another similar chamber, and the air going into the furnace passed through the hot chamber which gave up its heat to the air, the currents through the chambers being reversed at regular intervals. A few years later Sir William Siemens invented the gas-producer by which the solid fuel was treated in a specially contrived apparatus—the gas producer—and the resultant gases used to heat the furnace. In 1861 the regenerative furnace using gaseous fuel was used for melting glass, and its application to other industrial processes requiring great heat followed as a matter of course. The first application of the regenerative principle to the manufacture of iron was in the heating of the blast of a blast furnace, it was next used with gaseous fuel for melting steel in crucibles, and in 1867 Sir William



A SMALL SIEMENS-MARTIN EXPERIMENTAL FURNACE

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Siemens succeeded in employing it in the manufacture of steel from pig iron with ore in the open hearth furnace. M. Martin used scrap iron, or steel, instead of ore, and the process is known as the Siemens-Martin process, though strictly when ore is used it should be called the Siemens process, and when scrap alone is used the Martin process. The process itself is the same as that used by J. M. Heath about 1844, viz., melting wrought iron and pig iron together to form steel. The method failed at the time because of the lack of sufficient heat. The regenerative furnace provided this and the process at once became a success. The furnace was made to use only Hematite pig iron and very pure ore or scrap, and the interior of the furnace was necessarily of highly silicious material, but after the success of the Thomas Gilchrist process in the Bessemer converter endeavours were made to apply the same principles to the Siemens process. After much difficulty these efforts were successful and the Basic Open Hearth process has taken its place among the leading methods of steel-making of modern times.

The application of the regenerative principle in the Siemens furnace may be briefly described. Gaseous fuel is made in a producer by burning coal with a limited supply of air, so that carbon monoxide and not carbon dioxide is formed, and at the same time steam is blown over the incandescent coal and decomposed, and the proportion of carbon monoxide in the resulting gas is thereby largely increased, while the hydrogen greatly enhances the calorific power of the gas and moreover adds to its inflammability. This hot gas is passed through a chamber of chequered brickwork, called the regenerator chamber, which has been previously heated and the heat of the gas is greatly increased. Air is passed through a similar chamber

and heated to a high temperature, and the hot air and hot gas come together in the furnace when combustion at once takes place. The products of combustion pass out of the furnace at a very high temperature and are drawn through two chambers of chequered brick-work exactly similar to the two which the gas and air had passed through to the furnace. The heat in the now inert gas passes into the bricks of the chequer work, and then the passage of the gases is reversed by means of valves, the air and producer gas going through the now heated chambers and the exhausted gas going through the chambers which had been cooled by giving up their heat to the air and producer gas.

CHAPTER VI

THE ELECTRIC FURNACE

THE last development in steel-making is the electric furnace, the earliest form of which owes its origin to Sir William Siemens who, in 1878, patented an electric arc furnace. This furnace consisted of a closed vessel with a carbon rod fitted into the bottom projecting into the interior and connected with the positive pole of a dynamo or other electric generator. A second carbon rod was passed through the cover of the vessel and connected with the negative pole of the generator. The fragments of metal to be melted were placed near the positive pole in the vessel, and the current passing from the positive pole through the metal leaped to the negative pole, the arc being automatically regulated by a familiar electrical device. In 1880 Borchers introduced his resistance furnace in which a thin carbon rod was placed in line between two thick ones, and this becoming incandescent when the current passed imparted heat to the substance to be melted. Subsequently the principle of induction was applied and modern electric furnaces embrace all these types. The greatest advantage of the electric furnace is the high temperature which it develops. In the blast furnace the temperature may reach 1,200°C., and in the open hearth steel furnace nearly 3,500°C.

The place which the electric furnace will occupy in the metallurgy of iron is not yet fixed. Until quite recently two furnaces only, one in Norway and one in

California, were producing iron from the ore, and these only on a very small scale. Three furnaces are employed at Dommeldingen, in Germany, in converting pig iron into steel. The remaining electric furnaces in operation, probably seventy to eighty in number, are employed in refining or purifying steel.

In his Presidential Address to the Institute of Electrical Engineers on November 10th, 1910, Mr. S. Z. Ferranti referred to the question of the electric smelting of iron, and stated that with electric current at $\frac{1}{12}$d. per B.T. unit iron could be made as cheaply in the electric as in the blast furnace. From this it would appear that if the coal at the pit mouth could be converted into electricity on a large scale, and therefore cheaply, and conveyed without material loss to the ore and limestone, iron could be produced at a lower cost than in the blast furnace. It is this problem of cheap current and safe transmission which has to be solved, and when that is accomplished the blast furnace will gradually pass into the list of obsolete and antique things as the Catalan forge has already done.

But whether the electric furnace for smelting ore ever becomes practical on a large scale or not it will certainly be used, as it is at present, for the production of high-class steel from common materials such as Bessemer or Siemens steel, which will compete with crucible steel made from the best Swedish bars. It is also possible that it may be used for producing in quantity a steel midway in quality between crucible and open hearth steel; but the doubt as to this lies in the fact that very high quality steel can now be made in the ordinary open hearth furnace and with improved practice and larger experience it is possible that the quality may be brought much nearer that of crucible steel than it has hitherto been and

at a cost much below that of steel from the electric furnace.

Whenever steel of special quality is required in small quantities the electric furnace will be found in all probability to be the most suitable and the cheapest apparatus for its production.

THE PROCESSES AND PLANT USED IN IRON AND STEEL-MAKING

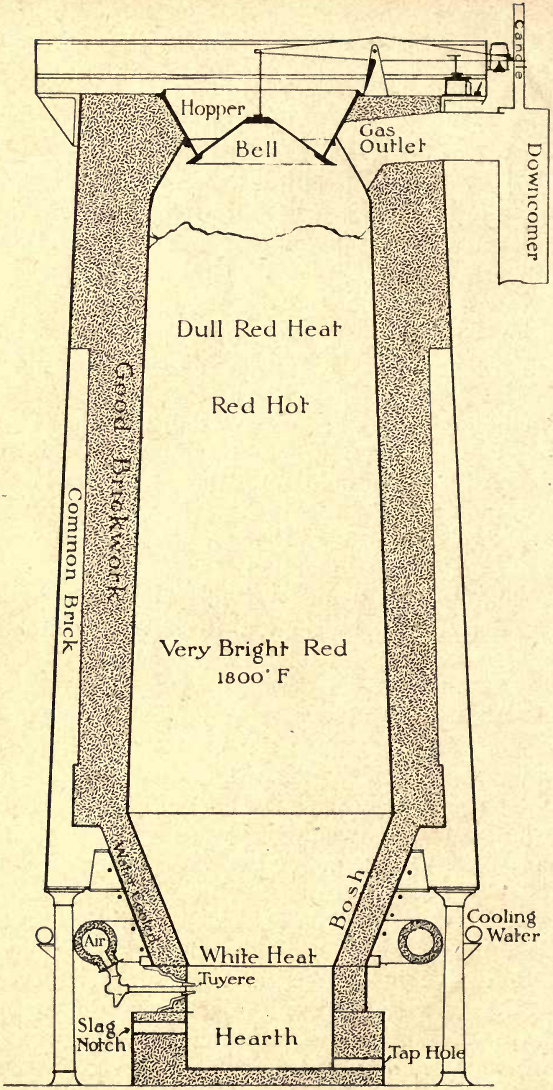
CHAPTER VII

THE BLAST FURNACE

THE most economical instrument for extracting iron from its ore is the blast furnace. Evolved from the earlier forms of Catalan forge and Stückofen it has reached a point of efficiency which it will be difficult to exceed. The earliest furnaces were open-topped, the flame streaming out into the air and lighting up the country all round. They were usually built by the side of a hill from which a gangway was made level with the top of the furnace along which the material was wheeled and tipped in. They were 35 to 40 feet high. A furnace in 1788 produced about 15½ tons of iron per week, and this output in 1796 had increased to 20 tons, in 1827 to 35 tons, in 1835 to 70 tons, in 1845 to 120 tons, in 1855 to 220 tons, in 1865 to 450 to 550 tons. To-day a Cleveland furnace will make 1,300 to 1,400 tons of Cleveland iron per week, and an American furnace producing hematite iron about 4,000 tons per week. In 1836 the attempt to utilise the gases escaping from the open-top brought about the change to the close-topped furnace. Up to about the end of the sixties the manufacture of iron in the blast furnace had been carried on almost by rule of thumb, reliance being placed on practical experience with very little theoretical knowledge About this time Sir Lowthian Bell, who as a man of scientific training as well as a practical ironmaster was especially qualified for the task, undertook

an enquiry into the chemical action which takes place in a blast furnace, the results of which were published in 1872 in his work on the *Chemical Phenomena of Iron Smelting*. This work is still the standard book on the subject, and it laid the foundation of all the scientific research which has subsequently been made into the facts of iron-making. The modern blast furnace has been evolved by combining the practical experience of the ironmaster with the scientific knowledge of the chemist and metallurgist and has probably reached its utmost development.

A section of a modern Cleveland furnace is here shown. A blast furnace and its functions can best be described by dividing it into three main parts, viz., the well, the bosh, and the stack. The well, as its name indicates, is at the bottom of the furnace and its function is to hold the slag and metal in the molten state. It is from 12 to 15 feet diameter inside and about 8 feet 6 inches deep. The walls are of the very best firebrick and are from 2 to 3 feet thick, they are often strengthened by means of heavy cast-iron jacket plates made in segments and bolted together round the outside of the brickwork. The bottom of the well—and therefore of the furnace—is called the hearth, and is formed of firebricks 3 or 4 feet in thickness. The "tapping-hole," through which the molten iron is let out of the furnace, is at the level of the hearth, and is a rectangular opening about 6 inches wide and 12 inches deep through the wall of the well. Near the top of the well are the tuyeres or nozzles, through which the hot blast passes, which may be eight to twelve in number and are arranged evenly round the furnace. These project into the furnace and have an annular space outside the blast passage through which cold water is circulated for cooling them. About two feet below the tuyeres is the "slag notch."



BLAST FURNACE

This is an opening in the wall of the well through which the slag, which is lighter than the iron and therefore floats on the top of it, is run out into ladles. When the iron reaches nearly to the top of the slag notch the furnace is tapped.

Immediately above the well is the bosh, or melting zone of the furnace. This is conical in form, sloping outward from the top of the well until a diameter of up to 20 feet is attained at the bottom of the stack, which is some 12 or 15 feet above the well. The walls of the bosh are of best fire-brick and vary according to the particular requirements and mode of working of the furnace. The brickwork is usually supported by an outer shell of boiler plates, and this is sometimes kept cool by water circulating in pipes round it and spraying it through small holes. Around the well outside are eight to twelve massive columns which support the entablature or base upon which the stack and its steel casing rest. The stack is the upper part of the furnace above the bosh. The interior is brickwork 3 or 4 feet thick, the inside diameter starting at the bottom at about 20 feet narrows to 15 or 16 feet at the throat where the charging hopper is placed centrally at the top of the furnace. The charging hopper is in the form of a truncated cone, apex downward, and the " bell " also a cone but with apex upward, fits into the downward open apex of the hopper, thus closing the top. The hopper is made of cast-iron plates bolted together, the bell usually of mild steel plates. The bell is suspended from the apex by a chain attached to a beam carried on bearings and having at its other end a weight to balance the weight of the bell. The bell is usually brought up tight to the hopper by a hand-winch.

Directly under the hopper, around the throat of the

furnace, are the gas outlets, one or more. These carry the gas produced in the furnace down in large tubes to the gas main, and immediately outside the furnace these tubes, or downcomers, are furnished with gas explosion valves. The outer casing of the stack is of steel plates and runs from the top of the bosh to the top of the furnace where the top platform is rivetted on gusset-plates to it. This platform is connected to the hoist by built-up girders secured to the framework of the hoist and the furnace shell, and where several furnaces are worked together it may be connected in the same way to another furnace.

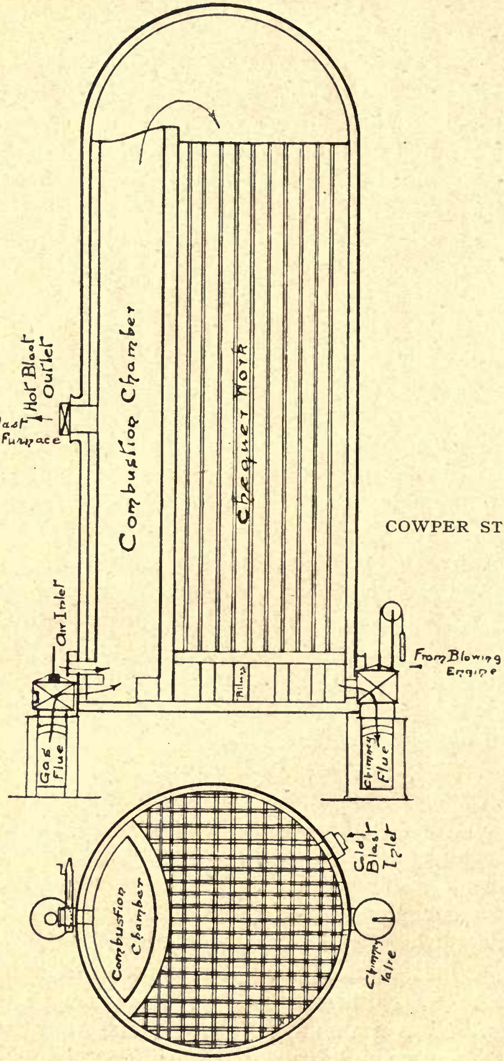
The columns carrying the furnace stack also support the "horse-shoe main," which is the tube, made of steel, and lined with firebrick through which the hot blast passes from the stoves to the furnace.

The blowing engines are usually driven by steam, but in some modern works large gas, turbine and electrical engines are used. The pressure at which the blast enters the furnaces is in works in Great Britain from four to twelve pounds per square inch and in America up to eleven or fifteen pounds. Every furnace should have its own blowing engine, but except in modern works the practice in this country is to blow several furnaces from a common main. In America furnaces are generally driven separately, and the same practice applies in Germany. The advantage of separate blowing is that the pressure can be made to suit the working of the furnace, whereas on a common main one furnace may be working well and another badly, but the extra pressure which would help the one would drive the other too hard and so cannot be applied.

The air passes from the blowing engine to the heating stoves, which are in groups, one stove heating the blast while the others are being heated by the gas. A section

of a Cowper stove is shown on p. 50. It consists of an upright round chamber 60 to 100 feet high and 20 to 26 feet diameter, with an outer casing and dome of steel plates, and an inner double wall of firebrick. The interior is divided up as shown in the plan and section. The blast furnace gas is turned into the stove through the gas flue, air being passed in through the air inlet. These meet in the combustion chamber. Combustion takes place, and the resulting hot gases pass over the top of the combustion chamber into and down the chequered brickwork, giving off heat to the bricks and then passing to the chimney. When the brickwork has got thoroughly hot the gas and air are turned off and the blast from the blowing engines is turned on through the cold air pipe. It is forced through the hot chequered brickwork and down the combustion chamber and leaves the stove at a temperature of 1,100° to 1,500°F. by the hot blast pipe, whence it goes direct to the horse-shoe main. When the brickwork has become partially cooled by the blast passing through it the valves are changed and the hot gas and air are again passed through, and so on continuously changing to hot gas or cold air. It is usual to run the blast through a stove for about an hour.

The gases passing out of the furnace into the down-comer are conveyed through dust-catchers where some of the dust which they carry is deposited. The dust is objectionable because in passing through the stoves it chokes up the passages. When the gas is used for driving gas engines it has to be cleaned until it is free from dust which, if left in would destroy the surface of the cylinders and choke the valves. Cleaning the gas is the great difficulty in the way of using it in gas engines. Many patents have been taken out for this purpose, and some have proved very effective, so that,



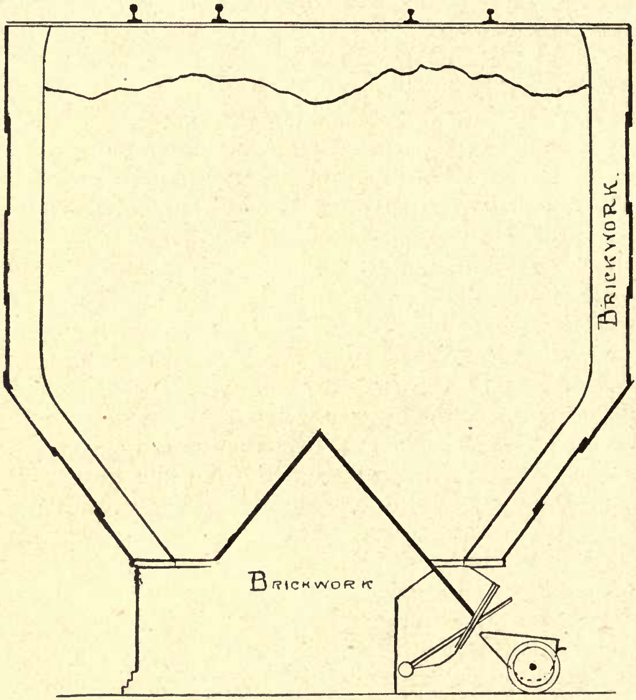
COWPER STOVE

in Germany especially, gas engines of great power driven by blast furnace gas have been erected. In England less use has been made of such gas engines partly because, owing to cheaper fuel being obtainable here, the saving would not be so great as it is in Germany, and partly because there has been less erection of new plant here than in Germany.

The arrangement for charging the furnace by filling the material into barrows, taking these to the top of the furnace on a hoist and tipping the contents into the bell, is being replaced by devices for filling, hoisting, and tipping the material automatically so that less labour is required and the furnace gases are not allowed to escape into the open air when the bell is lowered. The usual device is to have the materials tipped into a hopper below the ground level from which they are caught up by buckets on a conveyer working on an inclined plane up to the top of the furnace, where they are tipped into a receiver. This receiver is over the top of the furnace, and by an arrangement worked from the ground it drops the material into a second chamber from whence it passes into the furnace. The necessity of mechanical charging of furnaces arose in the United States owing to the ore smelting so easily that the furnaces could not be kept full with charging by hand. When mechanical charging was instituted the furnaces worked badly and the cause of this was found to be irregular distribution of the charge. The difficulty of the mechanical charging has been to get rid of this irregularity, and the number of devices to effect this is legion. If the furnace is to work properly the ore, coke and limestone must be evenly and intimately mixed and this is a very difficult thing to accomplish with mechanical charging.

In the manufacture of iron from the Cleveland iron-stone it is necessary to roast the stone before using it

in the blast furnace. This is done in kilns of a special construction which were invented by the late Mr. John Gjers, and a section of one of these is given. These



GJERS' CALCINING KILN

are formed of a cylindrical shell of steel plates from 20 to 30 feet in diameter lined with fire-brick about 18 inches thick. The bottom of the kiln is in the form of a cone made of cast-iron plates with the apex upward in the centre of the kiln. A fire is lighted and

proportionate quantities of coal and iron-stone are alternately filled until the kiln is full. As the stone is roasted it is withdrawn through the doors at the base of the internal cone, fresh iron-stone and coal being supplied to take the place of that withdrawn, and the process going on continuously. It has been found advantageous to calcine the limestone along with the iron-stone, and the two materials are tipped into the same kiln from the railway trucks which are run on a gantry over the top of the kilns. The object of the cone in the kiln is to force the material through the doors when they are opened so that it falls automatically into the barrows.

The effect of calcining the iron-stone is to eliminate moisture and to convert the carbonate of iron into peroxide, thereby greatly reducing the quantity of material to be dealt with in the blast furnace. One hundred tons of stone are thus reduced to a little over seventy tons, the iron is changed into a form which is more easily reduced and this at a very trifling cost. The coke is brought by rail and the trucks are taken by hoists, or by an inclined plane, to the top of the bunkers which are large hoppers with sliding doors underneath to allow the coke to be emptied into barrows. The railway trucks empty their burden of coke automatically into the bunkers. The coke-barrow is put under the door at the bottom of the bunker, the slide is drawn, the coke falls into the barrow, the door is shut and the barrow wheeled to the hoist where, in company with barrows of iron-stone, it is passed over a weighbridge and the weight made up to the exact quantity of the standard. It is then taken up the furnace hoist, which usually consists of two cages travelling vertically in a guiding framework and connected by a rope passing over a pulley at the top so that the descending cage with its empty barrows assists to pull

up the ascending cage and full barrows. The engine working the hoist has thus only to lift the weight of the material in the barrows.

A large quantity of water is used at the furnaces for cooling purposes and also for condensing steam, and to cool the water thus used, large cooling towers are employed in which the water is run in thin films over wooden laths. Pumps are employed to pump the water from the reservoir into which it runs from the cooling towers to the tuyeres, engines and condensers.

The products of the blast furnace are pig iron, slag and gas. As the ore is reduced the molten iron falls to the bottom of the furnace and accumulates on the hearth. The slag collects on the top of it and is run off at the "slag notch" into ladles and carried away as waste material except such small proporton of it as is required for making slag bricks, slag cement, flags for paths, imitation stone and other similar things for which it is now used. The iron is tapped three or four times every twenty-four hours through the tapping-hole which opens into the hearth and is closed by a plug of clay which has to be cut through at each tapping. The iron runs out along a channel made in the sand into the pig bed. The pig bed is a large bed of sand close to the furnace which slopes gently away from it. Depressions are made in the sand with a wooden pattern to form the mould for the iron to run into and form pigs. Rows of pig moulds are made across the bed, and across the ends of the rows a channel is cut which is easily connected with the main runner from the furnace. The iron from the furnace runs first to the farther part of the bed along the main channel or runner, it there turns into the channel between the pig moulds and runs to the end of that and then into the pig moulds. When all the pig moulds in that channel are filled, an opening

is made into the next channel between the next two sets of pig moulds and the iron flows into that, the passage to the farther channel being blocked by an iron spade called a "shutter," and so on until all the iron has run out.

The iron in the main channel from the furnace is called a runner, and that from the secondary channel between the pigs is called a sow.

When the iron on the beds has quite set but is still hot the pigs are broken off the sows with heavy hammers and the sows and runners are broken into convenient pieces for handling. The pigs weigh a little over a hundredweight each.

The quality of the iron is ascertained by breaking several pigs in each bed, the appearance of the fracture indicating the quality. In the best iron the crystals are large and the grain open, and as the quality falls the grain is closer and the crystals smaller until in white iron the fracture is almost smooth. The only exception is when an excess of silicon in the iron causes it to glaze so that the fracture looks rather like that of white iron, though it is really, save for silicon, better than No. 1. In the case of Cleveland iron the qualities usually graded are numbers one, three, four foundry, four forge, mottled and white. No. 2 is seldom selected. No. 3 is the standard grade for foundry purposes and No. 4 forge for the puddling furnace. Hematite iron is graded in numbers one, two, and three, which are usually sold in equal proportions as "mixed numbers." No. 4, mottled and white, are made in comparatively small quantities. Other districts grade on similar lines but making more grades for the qualities which are most in demand. Thus, in the Midlands there are eight grades, from one to eight, and in America no less than ten qualities are graded. In America, and also to a

less extent in Germany, the quality is ascertained by analysis for silicon, sulphur and combined carbon. This involves taking an analysis of every cast of iron and probably making two or three tests for each cast, and although the method is more certain and exact than grading by fracture it is not always necessary. When iron is made from the same quality of ore, coke and limestone in the same furnace the fracture is a reliable indication of the quality when the iron is cooled under the same conditions. For this reason the ironmasters of Cleveland have hitherto declined to sell their iron on the basis of analysis. It is probable, however, that as more scientific methods come into use in the foundries more exact knowledge of the composition of the iron put into the cupola will be required and the pig iron makers will then have to guarantee the analysis within limits. In the case of Cleveland iron this would probably only be required for silicon because the sulphur, combined carbon and manganese vary within very small limits. In the case of silicon the variation is large, good No. 3 being made containing less than 1·75 per cent. and also with up to 4 per cent., above which the iron glazes. It would not be a difficult matter to make a test for silicon on each cast, but it would involve keeping a more varied stock, and this might be a difficulty at some works.

When blast furnaces are worked in connection with steel plant the iron is not sent down the pig beds but is run into large brick-lined ladles which are emptied into the metal mixer. Metal mixers were originally built with the object of giving a more uniform quality of iron for the steel furnaces than was obtainable by taking the iron direct from the blast furnaces. They are now used also to eliminate some of the silicon and sulphur in the iron and thus do part of the work which

previously had to be done in the steel furnace. For this purpose they have to be heated by gas, and as scrap, iron ore and limestone are put in to assist the operations they are really in the nature of a furnace for preliminary treatment of the iron. From the metal mixer the iron is poured into a ladle which transfers it to the steel furnace.

STEEL FURNACES AND PROCESSES

CHAPTER VIII

THE ACID OPEN HEARTH PROCESS

THE furnace is built of silica bricks and the bottom plates, which are of thick iron, are covered with two courses of bricks of the same kind. The bottom is made of sand and this is burnt in in layers. When the bottom is finished and formed to the right saucer-like shape with a slope towards the middle of the back where the tap-hole is made, a last layer of slag is burnt in. The furnace is then heated and the tap-hole having been closed with clay the charge is introduced. The bottom is covered with pig iron and then scrap is put in on the top ; where molten iron is used the scrap is generally put in first. When this is melted a sample is drawn and the "first hand" gauges the carbon. Ore is then thrown in to oxidise the excess of carbon, for at this stage all the silicon will have been eliminated, and when the carbon in the bath is low enough the tap-hole is opened and the metal and slag are run into a ladle big enough to hold the whole charge.

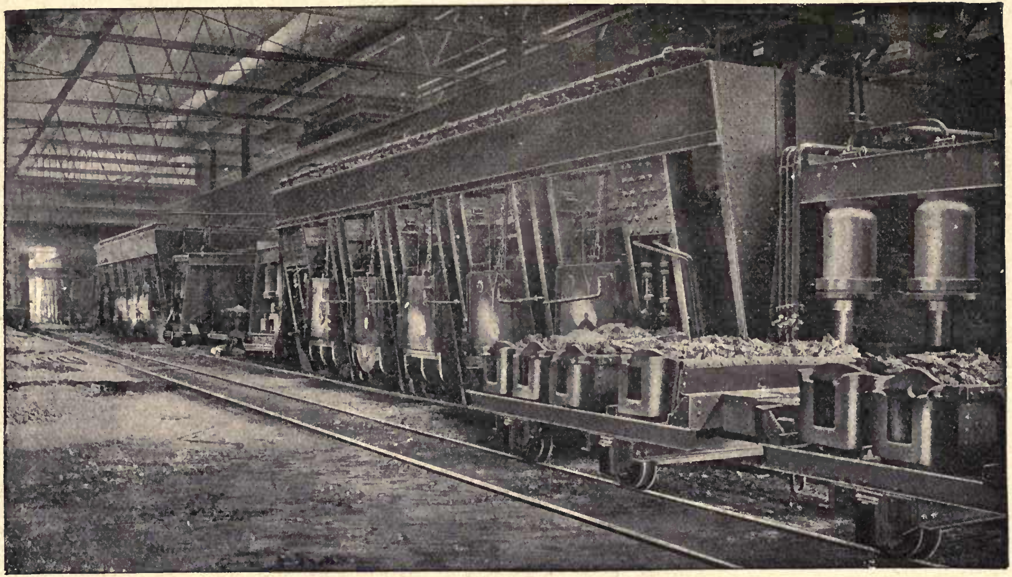
THE BASIC OPEN HEARTH PROCESS

The furnace in this process is built of silica bricks which do not come in contact with the metal and of magnesite bricks for the parts which the metal covers, with a neutral (usually chrome) brick between. The bottom and sides of the hearth to the level of the fore-plate, that is, the bottom of the charging doors, are of

magnesite; above this is a course of neutral bricks and above this the silica bricks. As in the acid furnace the bottom is burnt in layer by layer, but in this case the materials are different. The first layers consist of fine basic slag and burnt dolomite ($CaCO_3$ $MgCO_3$). The amount of slag is gradually diminished and finally only dolomite is used. In some cases the bottom is made by ramming a mixture of ground dolomite and hot tar with red-hot rammers, but this does not give such a dense bank. A tap-hole is cut out, and when the furnace is ready to charge this is closed with a mixture of ground dolomite and fine anthracite coal, rammed tight. Then the necessary quantities of limestone and iron ore are put in either by hand or machine, and next the metal from the mixer is poured in. In a few hours the ore and limestone have melted and a sample is drawn and tested. The quantity of ore required is estimated from the test, and this is thrown in gradually together with lime, fluor spar and blacksmith's or mill scale (oxide of iron) to keep the slag basic and of the right composition. The oxygen in these materials removes the carbon and enables the slag to take up the phosphorus and sulphur. In this process the slag plays a much more important part than in the acid process. Samples are drawn at intervals and analysed, and when the metal is of the quality required and the slag of the right composition the temperature of the bath is taken. This is done by thrusting a long iron bar into the bath and moving it from side to side slowly for about half a minute. From the condition of the burnt-off end when it is drawn out the foreman of the furnace, or sample-passer as he is called, knows if the metal is hot enough to tap. To tap the furnace a long steel bar about 1¼ inches in diameter is driven up the tap-hole from the back; as soon as it is right through

into the furnace it is knocked out. The molten steel follows it out and runs down a chute or lander into a ladle. If the carbon in the steel is not high enough, carbon in the form of fine anthracite coal is put into the ladle just before tapping. While the steel is running into the ladle ferro manganese, and if necessary, ferro silicon are added. This quietens the metal in the ladle, helps the formation of sound ingots, and provides the requisite quantity of manganese and silicon in the steel. All the steel and slag runs into the ladle, the surplus slag, which the ladle will not hold, running over the lip of the ladle into pans placed in the casting pit. As soon as the furnace is empty the stoppers of the holes in the bottom of the ladle are raised and the metal runs out through these holes, which are about 1½ inches in diameter, into the ingot moulds. As the moulds are being filled small pieces of aluminium are thrown in from time to time. This is done for the purpose of preventing blow holes which are caused by gases dissolved in the steel while it is molten, but which separate out when it solidifies. The aluminium is supposed to render the steel incapable of retaining the gases. The ingots are allowed to stand for about half an hour, and the moulds are then stripped from them.

There are various modifications of the plant of the open hearth process which should be referred to. The principal of these are the Bertrand-Thiel process and the Talbot process. In the former two furnaces are used, one called the primary and the other the secondary furnace. The charge is put into the primary furnace and worked at a comparatively low heat and the phosphorus and silicon are largely removed. It is then poured into the secondary furnace in which the ore or scrap has been previously placed and heated and the charge worked again. The furnaces are not fixed but



TALBOT TILTING STEEL FURNACES

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made to tilt by means of rollers or rockers, and thus the liquid metal is easily poured from the primary to the secondary furnace. The advantage claimed for the system is a larger output at a cheaper cost and less slag. The Talbot furnace is a large tilting furnace which, while working, is never completely emptied. When the furnace is tapped only about a third of the steel is drawn off and immediately fresh additions of metal ore and limestone are made to the charge, so that the furnace is constantly being partially emptied and refilled. The principal advantages claimed for this furnace are that it gives a greater yield and larger output, a more regular supply of ingots, a reduced cost of repairs and cheaper labour than the ordinary fixed furnace. There are a number of works in this country using this furnace.

These systems have met with a considerable amount of success, but time alone will show whether they can compete successfully with the simple open hearth furnace by which such excellent results are obtained both in quantity and quality.

The Bessemer plant and process, both acid and basic, have already been sufficiently referred to.

COMPARISON OF THE FOUR STEEL PROCESSES

The relative merits of the Bessemer, acid and basic, and the open hearth, acid and basic, processes may be very generally indicated. The Bessemer, as the earlier process, has been longer established and a great deal of capital has been sunk in plant at various places for carrying it on. Therefore, so long as a profit can be made in working it the process will survive, but no one putting down new plant in Great Britain to-day would adopt it, so that its disappearance is only a question

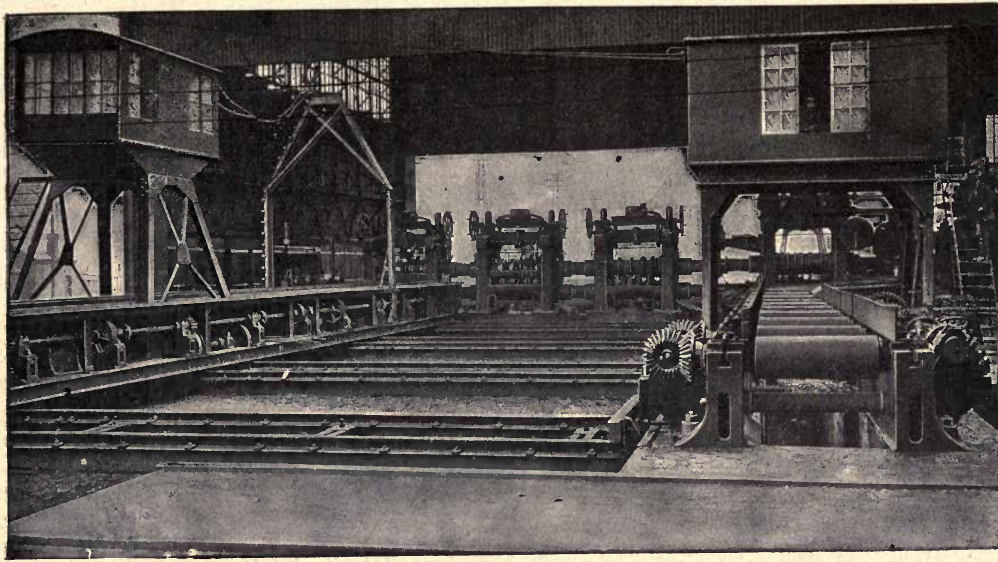
of time. The Bessemer process has one advantage over that of Siemens in the largeness of output, due to the rapidity of working. But the yield per ton of iron is not so great, and the steel is not so reliable in quality. Specifications cannot be worked to so closely because the steel is more irregular, and this is the great drawback to the Bessemer process. In these days of high-class material with great regularity of quality and exact specification of chemical composition, the steel which is irregular and uncertain in quality is at a great disadvantage compared with that which can be produced exactly and uniformly to fulfil given conditions.

The basic Bessemer has all the disadvantages of the acid Bessemer process as to quality with the one great advantage that a cheap iron containing phosphorus can be used, and the slag obtained is consequently of considerable value as a manure. But in order to obtain the richest slag it is necessary to use iron with 2 per cent. and upwards of phosphorus, and in Great Britain this is a very scarce article. To obtain it the burden of the blast furnace has to be enriched in phosphorus by using puddler's tap, the slag from the puddling furnaces, which was found in heaps wherever puddling had been carried on. These heaps have now been almost exhausted, and only the cinder from the puddling furnaces now working is therefore available. The greater part of the common iron made in this country does not contain sufficient phosphorus to be used advantageously in the basic Bessemer process and therefore this process has not been largely installed.

The open hearth acid process turns out a much smaller quantity of steel than the Bessemer and is more costly to work, but it allows of the use of scrap in large quantities, the consumption of iron per ton of steel is smaller, the exact composition of that iron need not be

so uniform and, most important of all, the quality of the steel can be regulated exactly as required.

The basic open hearth is a slower and more expensive process to work, but otherwise has all the advantages of the acid open hearth over the Bessemer with the additional one of using any kind of ordinary iron, no matter what its composition. Iron with 2 per cent. phosphorus or with 2½ per cent. silicon, or with a tenth of one per cent. of sulphur, can be converted into steel of the highest ordinary quality by this process. There does not appear to be much doubt that it is the process which will be most largely used in the future and will probably supersede most of the others. When that takes place the manufacture of pig iron will have returned to the general conditions which prevailed before Bessemer invented his process. At that time there was no special reason for making pig iron very low in phosphorus and sulphur. The requirements of the acid Bessemer process created the trade in pure ores from Spain and elsewhere, and the manufacture of hematite iron was the result. This manufacture has been of enormous advantage to the Spanish mine-owners who have made fortunes out of the pure ores from Bilbao. But when the necessity for iron low in phosphorus for the manufacture of steel passes away the demand for these ores will gradually decline in importance in comparison with that for inferior ores. Purity as regards phosphorus and sulphur will not be of such high relative value. Ores will then be valued according to the cost of making good steel out of them by the process for which they are best suited. It is true that at present there is no indication of such a change as has been indicated but rather the reverse, for best Rubio ore is at present dearer than it has probably ever been before and the demand for it greater. But it appears to be a logical



32″ FINISHING MILL WITH LIVE ROLLER GEAR

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deduction from the present situation of the steel manufacture and the direction in which it is developing that such a change should take place in the future.

In other countries than Great Britain the same processes of selection are going on and "the survival of the fittest" will probably have the same result. In Germany, however, it will be long before the Bessemer process succumbs. It was a strange turn of fortune that the basic Bessemer process which was sought so ardently and persistently for many years by the best brains in England with the sole object of utilising the common iron-stone of Cleveland for the manufacture of steel, and was ultimately found by a Welshman, proved to be of supreme importance to Germany, France, and Belgium, and comparatively of very small advantage to Great Britain. It is no exaggeration to say that to this one invention, made with the object of benefiting England alone, is due the large increase in the iron and steel trade of Germany during the last thirty years. In proof of this it is only necessary to point out that of eleven million tons of steel made in Germany in 1908, nearly ten and a half millions were made by the basic process, Bessemer and open hearth. The chief reason for this is, of course, that the iron from the ores of Luxemburg and Lothringen is exactly suited to the basic Bessemer converter, and the slag made from them is exceptionally high in phosphoric acid and therefore very valuable, whereas the iron from the lean stone of Cleveland is not nearly so suitable for the process.

The present position of the acid and basic processes in relation to the total production of steel is indicated by the statistics published in the *Iron and Coal Trades Review* of November 18th, 1910, relating to the production of steel in Great Britain, Germany and the United States.

These are as follows:

	Great Britain.		Germany.	
	Acid Steel.	Basic Steel.	Acid Steel.	Basic Steel.
1902 .	3,833,888	1,075,179	517,996	7,262,686
1903 .	3,930,189	1,103,912	613,399	8,188,116
1904 .	3,712,506	1,314,373	554,288	8,223,189
1905 .	4,439,067	1,373,215	655,495	9,290,269
1906 .	4,685,840	1,776,434	715,952	10,419,133
1907 .	4,665,095	1,857,653	685,161	11,378,471
1908 .	3,485,306	1,810,336	598,311	10,480,349
1909 .	3,874,200	2,007,428	462,960	11,485,032

	United States.		Total of three Countries.	
	Acid Steel.	Basic Steel.	Acid Steel.	Basic Steel
1902 .	10,329,559	4,496,533	14,681,443	12,834,398
1903 .	9,687,827	4,734,913	14,231,415	14,026,941
1904 .	8,660,939	5,106,367	12,927,733	14,643,929
1905 .	12,097,023	7,815,728	17,191,585	18,479,239
1906 .	13,596,866	9,649,385	18,998,658	21,844,952
1907 .	12,937,900	10,279,000	18,287,356	23,515,124
1908 .	6,812,000	7,140,400	10,895,617	19,431,085
1909 .	10,407,200	13,417,400	14,744,360	26,909,860

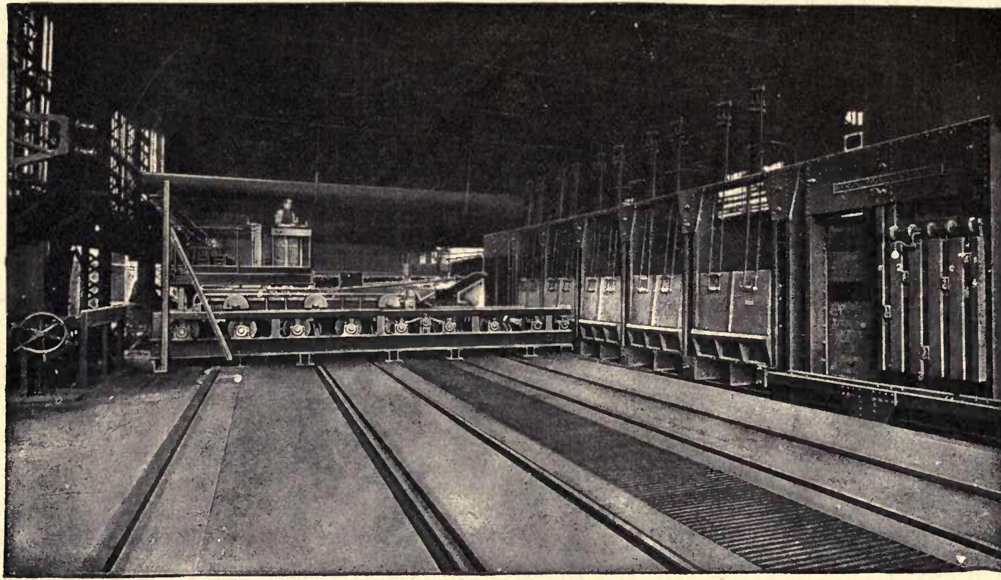
From these figures it will be seen that the whole increase in steel production during these eight years has been in the basic output, the output of acid steel being practically the same at the beginning and end of the period. In all probability the output of acid steel will decrease in the future and that of basic steel increase.

Before leaving the basic Bessemer process, reference should be made to the utilisation of the slag made by it. When the process was first used attention was drawn to the richness of the slag in phosphoric acid and its consequent value as manure. Experiments were tried for using it by breaking it up into small pieces and putting it on the land. It had, however, no effect on the crops, and attention was then turned to methods of extracting the phosphoric acid, which was necessarily a costly process. Before these could be put into operation someone suggested grinding the slag into fine powder. When this was done it was found to be quite a success, the plants being able to assimilate

the phosphorus from the minute grains, which they were unable to do from the large pieces. The slag at once became a valuable commodity, worth up to 25s. per ton according to the quantity of phosphoric acid which it contained. The discovery of the value of the slag saved the basic Bessemer process from failure in this country and enabled it to be carried on when the only profit was produced by the slag.

INGOTS AND THEIR SUBSEQUENT TREATMENT

When the steel is to be used for making castings it is taken direct to the foundry and used there in much the same way as iron is used, except that it requires no purifying. For all other purposes it is run from the ladles into ingot moulds. When the steel in the mould has solidified, the mould is "stripped" from the ingot, and if it is to be used at once the ingot is sent to the soaking pit or re-heating furnace. The use of the soaking furnace is to render the ingot uniformly hot all over. It naturally solidifies first at the outside, the interior remaining liquid longer and solidifying much more slowly, so that if it were sent to be rolled at once part of it would be too soft and part too hard. The soaking pit was invented by Mr. John Gjers, and consists of a brick-lined chamber in the ground, large enough to hold the ingot easily and covered with a lid. The ingot parts with its heat to the bricks until the whole chamber and ingot are at the same temperature throughout. The chamber retains the heat after the first ingot is taken out, and when the next ingot is put in the chamber is hotter than the outside of the ingot and gets "soaked" more quickly. The soaking pit answered admirably with Bessemer plant because the ingots arrived at quick and regular intervals so that the mills could be "fed" regularly from the pits. With open



RE-HEATING FURNACES AND "COLLIN" CHARGER

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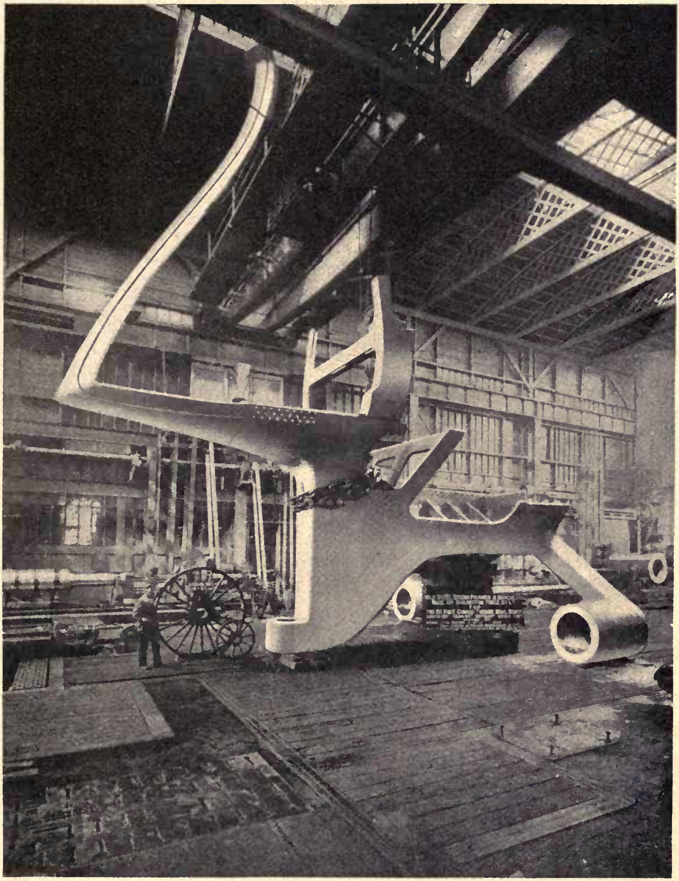
hearth furnaces, however, and when cold ingots were required to be used gas or coal-fired re-heating furnaces became necessary, because the ingots arrived very irregularly and at uncertain times. These furnaces are made to hold a number of ingots, and the temperature can be regulated as required.

From the soaking pit or re-heating furnace the ingots are withdrawn by a crane and passed automatically to the rolling mills. First they go through the cogging-mill, which reduces the ingot to a long square lump of steel. This is passed on to the roughing and finishing rolls which squeeze it to its final shape of bar or rail or girder. For making plates the cogging-mill shapes the ingot into a flat slab which is then sent to the re-heating furnace, because it cools very quickly in this form and would not roll. For dealing with steel in the manufacture of articles too large to be rolled, hydraulic presses of great power are employed. These are made for pressures up to 12,000 tons, and by their means forgings of 100 tons or more can be dealt with. An illustration of such a forging is given on p. 71. This is the sternframe and brackets of the *Mauretania,* made by the Darlington Forge Co., which together weighed over 100 tons.



MILD STEEL STERNFRAMES AND BRACKETS FOR 25-KNOT CUNARD TURBINE MAIL BOATS, "MAURETANIA" AND "LUSITANIA"

CHAPTER IX

FOUNDRY IRON

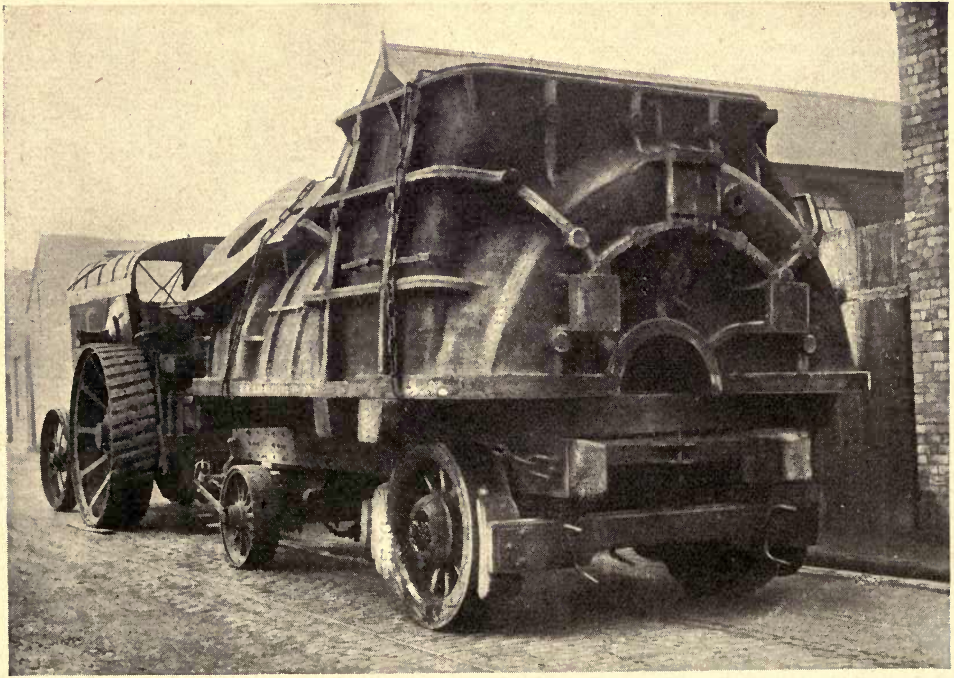
WHEN blast furnaces produce ordinary pig iron not used for steel-making, the higher or foundry qualities are used for making castings and the lower, or forge qualities, for making malleable iron. The foundry trade is one of wide distribution and infinite variety. There is probably not a single town in the country which does not contain a foundry. Every trade, every industry is largely dependent on the founder ; railways, ships, houses, waterworks, gas-works, machinery, all call for castings and would get on very badly without them. And the articles which are produced are of the most diverse character. Tubes for the underground railways of London, turbine castings, thirty to forty tons each, for battleships, small parts of sewing machines an ounce or so each, huge water pipes, tiny brackets half an inch long for shelves, railway sleepers, small nails, long heavy columns are alike made by the experienced founder.

The iron in the form of pig is re-melted in a cupola, which is a kind of small blast furnace. Wrought scrap iron is added to the charge to reduce the cost of the resulting metal or improve its quality. In countries where scrap iron is plentiful and cheap and pig iron costly the largest possible amount of scrap is added, and the pig iron which will "carry" the largest quantity of scrap is the best liked.

The cupola is a tall cylindrical vessel of fire-brick cased with iron plates. The raw material, coke and iron and scrap, is put in through a door opening near the

top. Near the bottom are holes for the tuyeres. An opening at the bottom forms a tap-hole. In starting the cupola wood is put on the flat hearth and lighted, coke is then added, and then layers of coke, pig iron broken into pieces, scrap and a little limestone. When the charge has burnt up, the tuyeres are put in and the blast started. When the metal runs down it is tapped off into a hand-ladle or run direct into the moulds. The effect of the re-melting of the iron is to reduce the silicon, and consequently to increase the proportion of combined carbon and decrease the proportion of graphitic carbon.

The consumption of fuel varies very much, being as low as one cwt. in the largest cupolas and as high as three and a half cwts. in smaller ones per ton of iron melted. The quality of a casting must depend on the work it has to do and the work which has to be done on it before it is put into use. There is one clear distinction in castings, viz., those which have to be machined and those which have not. If a casting has to have any serious amount of machine work done on it in the way of planing or boring it must not be so hard that the tools are unduly worn in the operation. If a casting has not to be machined its hardness does not matter. Hardness is caused by an excess of combined carbon, and this is generally due to the silicon being too low. But iron low in silicon is stronger than iron high in silicon, and therefore where strength is necessary the iron must not have too much silicon in it. What then has the perplexed founder to do if he wants a strong casting which has to be machined? There are plenty of problems of this kind for the founder which he has to settle as best he can. Attention is being given to the scientific examination of these problems, which may render the work of founding less of a rule-of-thumb



J. Downey & Sons] [*South Shields.*

TOP HALF OF L. P. TURBINE CYLINDER, WEIGHT 25 TONS. CASTINGS MADE FOR H.M.S. "TEMERAIRE" AND "COLLINGWOOD"

business than it has been in the past. There is no branch of the iron trade which has received less attention in this respect than the foundry trade.

In actual practice it is not usual to use only one quality or brand of iron except for common and heavy work. Where strength and soundness are required a mixture of Scotch and Cleveland, or hematite and Cleveland is said to give the best results. For large pipes which have great weight Cleveland four foundry is much in favour in Scotland and elsewhere, but for castings which have to stand tensile and pressure tests number three and number one are used with a small admixture of hematite or Scotch. The huge turbine castings for the big battleships are made from Cleveland iron with an admixture of Scotch, and some of these castings, which have to stand a water pressure test and must therefore be quite sound, have a grain as fine as first-class steel and weigh up to forty-five tons.

The excellent qualities of Scotch iron for foundry purposes are known all over the world, and Cleveland iron has become no less famous. The two qualities combined probably give the finest mixture which it is possible to have for general foundry work, the Cleveland giving rigidity and body to the milder qualities of the Scotch and the Scotch modifying the hardness of the Cleveland.

THE FORGE

The lower qualities of iron from the blast furnace are used in the forge for making malleable iron. The iron is melted in a reverberatory or puddling furnace, an illustration of which is given on page 80. This furnace has not greatly altered in form since it was invented by Cort and modified by Rogers. The flame is separated from the hearth by a low partition or bridge which prevents the fuel mixing with the iron.

The flame passing over the bridge parts with its heat mainly to the roof above but partly also to the metal on the hearth below. From the roof the heat is reverberated or reflected back on to the metal on the hearth, which is thus melted. The gases pass on up the chimney, above the top of which a metal plate is suspended which enables the draught of the furnace to be regulated. A stream of water circulates round the body of the furnace and this preserves the fabric by counteracting the effect of the intense heat to which it is subjected.

The puddler effects his operations by means of an iron tool called a rabble through a door opening on to the hearth. The labour of puddling is very exhausting, and large sums of money have been spent in endeavours to do the work mechanically. The rotary puddling furnace of Mr. Danks, of Cincinnati, most nearly achieved success, and it was investigated in America by a party of English ironmasters who reported favourably upon it. It was tried in Middlesbrough in 1872 but was ultimately abandoned, and puddling to-day remains practically where Cort and Rogers left it in 1816. The bottom of the hearth is an iron plate which is covered with "fettling," which is usually hematite ore, purple ore, or similar material, and some clean scrap iron. These are heated and worked over the bottom to give a good layer of iron oxide. The pig iron is broken into small pieces and then put into the furnace on the top of the fettling. After the charge is melted, slag forms and the iron boils in consequence of the heat evolved by the combination of the carbon in the pig iron with the oxygen in the fettling. Gradually the boiling subsides and the charge becomes pasty and is worked by the puddler into balls which are now malleable iron, the excess of carbon having been oxidised. The balls, or puddled blooms, as they are called, are removed from the furnace and

immediately put under a powerful hammer and hammered into shape for the mill. The process of hammering also expels the slag which gets mixed in with the iron in the furnace. The bloom is next passed to the rolls and rolled into puddled bars. These bars are passed to the mills for conversion into the finished bar or rail. They are first cut up usually into pieces of one to four feet in length, and these pieces are piled together into squares. The piles are put into the mill furnace, which is a small reverberatory reheating furnace, similar to the puddling furnace, and heated, and as soon as they are hot enough they are removed from the furnace and sent direct to the rolls where they are rolled into finished bars, rails, or sheets exactly the same as in the case of steel ingots.

The process of puddling is modified in different districts, and in the manufacture of "best Yorkshire iron," a special production of very high quality of which the brand "Low Moor" is the best known, the pig iron is first put into a refining furnace where the silicon and part of the phosphorus are extracted and the carbon changed into the combined form. It is then transferred to a puddling furnace, which differs from the usual type in having a chamber beneath the chimney in which the charge is heated before being put on the hearth. The hearth has only the iron bottom, no fettling being required, as the silicon and phosphorus have already been removed. The charge is kept in a pasty condition until the carbon has been removed and is then balled and sent to the hammer. The super-excellence of this iron is said to be due as much to the care in its manufacture as to the processes it passes through. It is made from cold blast pig iron containing 1 to 1½ per cent. silicon, ½ per cent. phosphorus, and about 3½ per cent. carbon.

SMITHING OR SETTING CIRCULAR SAWS

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OTHER PROCESSES

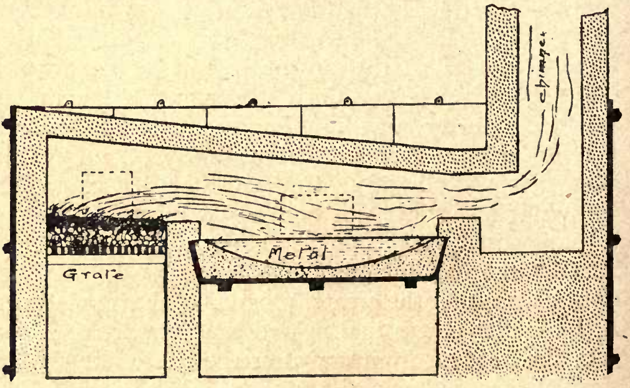
There are many other processes in connection with the different manufactures of iron and steel which cannot be dealt with here. Principal among these is the manufacture of tinned plates which are rolled from steel billets. The home of this important trade is in South Wales, and although efforts have been made to establish it in other places, and America has done what she could to capture it, it flourishes there more vigorously than ever, aided no doubt by cheap raw material brought to its doors from many lands, and by the accumulated experience of many generations of its workers.

The manufacture of pipes and tubing of wrought iron and steel, of special steel for motor-cars and machinery requiring great strength and reliability, of hard steel for armour-plates, of huge steel castings for ships, and of tool steel, are a few of the specialities which are important branches of the iron and steel trades but cannot be more than mentioned by name.

In closing this brief account of the manufacture of iron and steel, it is interesting to note that most of the great discoveries and inventions in connection with it have been made either by natives of, or residents in Great Britain. Henry Cort, who laid the foundations of the industry, was an Englishman. Neilson, the inventor of the hot blast, was a Scotsman. Henry Bessemer was born in England of French parents. Sir William Siemens was born in Germany but became a naturalised Englishman. Sidney Gilchrist Thomas was a Welshman living in London.

One reason for the greater progress of the iron industry in its earlier stages in England than on the Continent was the freedom from war after the Restoration, which enabled peaceful pursuits and trade to be carried on

quietly and steadily, whereas the wars which devastated great countries on the Continent in the late eighteenth and early nineteenth centuries destroyed the trade and ruined industry there for the time being. The great inventions of Watt and Stephenson, which resulted in the building of railways and the development of all industries were at a later period the cause of this country taking the lead in the development of the iron trade which it has only lost in recent years to the Americans because of the rapid development of their immense country and to the Germans because of their great resources of native ore and the skill and energy by which these have been utilised. The leaders of the industry in these two great countries have frequently expressed their indebtedness to the ironmasters of Great Britain, and it is a notable fact that until recent years it was to Great Britain that the ironmasters of the rest of the world came for "light and leading." The first application of modern scientific principles to iron-making was made in this country by Sir Lowthian Bell, whose work on the smelting of iron remains the highest authority to-day.



SECTION OF PUDDLING FURNACE

THE IRON TRADE

CHAPTER X

THE HISTORY OF THE TRADE IN IRON

SUCH a history begins with the barter by the hunter, fresh from the chase, of the skins of his quarry for an iron tool with which to take off the pelt, or by the tiller of the ground of the grain he had grown for iron to make a shoe for the point of his wooden ploughshare. There is no record of these early transactions, there were no weekly iron markets, no quoted prices, no questions of "bull" or "bear" or "corners," or any of the mischievous devices of modern commerce in those days. The necessities of the seller and the wealth of the buyer, who were also producer and consumer, fixed the price to be paid and received. As the production of iron increased and the use of it extended its value as a regular article of commerce would become more fixed. There seem to be no records of prices until about 1638 when Dud Dudley sold iron made with pit coal at £12 per ton, but this is comparatively a modern date.

The earliest record of iron-making is the reference in Genesis to Tubal Cain as "An instructor of every artificer in brass and iron." He was evidently the first expert in the trade which must, therefore, have reached a very considerable degree of efficiency in his day. The records of the earliest civilisation of the world, that of Egypt, contain many references to steel and iron, and the metal was known to the Chaldeans, Babylonians and Assyrians. Early Biblical references to iron are numerous, one of the most curious being that of the iron bedstead of Og, the King of Bashan. Goliath's spearhead weighed six hundred shekels of iron. Job

GLASGOW EXCHANGE; THE IRON "RING" IN SESSION

By special permission of the Scotch Pig-Iron Association

refers to the iron weapon and the bow of steel and various tools of iron are referred to by David. Daniel wrote " iron breaketh in pieces and subdueth all things," and Elisha made the iron axe to swim when it fell into the water, and the servant lamented because it was borrowed. The Medes and Persians, and the natives of India, were acquainted with the manufacture, and Wootz steel has been famous for ages and is yet preferred by the native swordmakers for the best weapons. The Arabs were early makers of fine steel and iron, as also were the Turks. It is recorded of Saladin that his sword was of such fine edge that he severed with it a down cushion thrown in the air.

The Greeks were well acquainted with the manufacture of iron, and reference to it is made by Homer. In later times the ores of the Isle of Elba were worked by the Greeks. The Romans knew the value of iron, but they were not great manufacturers of it themselves. The Celtibarians of Spain were famous makers of iron and steel, and Diodorus says their swords " cut through everything in their way that neither shield, helmet nor bone can withstand them." The ancient Britons knew the value of iron and used it for various purposes, and it is probable that they were acquainted with its manufacture from the ore, although it is quite possible that it was at first imported by the Phœnicians and other traders who came to the Cornish ports for tin. By the time of the first Roman invasion iron was made in the Island, and during the Roman occupation the manufacture of it was carried on in various parts of the country on a large scale. Enormous cinder beds in Monmouthshire and similar remains of iron smelting in other parts of the country in which Roman coins have been found, testify to the importance of the industry in those times.

In Anglo-Saxon and Danish times the manufacture of iron was an important industry, the monks even engaging in it, and St. Dunstan is said to have had a forge in his bedroom. In Domesday Book ironworks in Somerset, Hereford, Gloucester, Cheshire and Lincoln are referred to. Gloucester appears to have been a centre of the trade, and its tribute to the King was paid in iron. Scrivenor says that from the Conquest to the end of the reign of King John iron and steel were imported from Germany, which probably indicates that industries in England were flourishing and iron could not be made in sufficient quantity. During the Crusades, the art of making chain armour was carried to great perfection in England, and the same perfection in making weapons had been reached by the Saracens. In the reign of Edward the Third a law was passed prohibiting the export of iron, whether made in the country or imported. The magistrates were authorised to regulate the price and to punish anyone who charged too much. In this reign cannon are first mentioned, and these were first made of iron. Scrivenor says that during the fourteenth and fifteenth centuries iron and steel were imported from Germany, Prussia and other places, and iron from Spain, but as several improvements in the manufacture had taken place during this period in England laws were made towards the end of it against importing any of the articles of iron and steel which were manufactured in this country. The makers of these articles in London and other towns presented a petition to Parliament in 1483 and an Act was passed prohibiting their importation.

The trade continued to flourish in the Forest of Dean, Sussex, Somersetshire and Yorkshire until 1558, when an Act was passed prohibiting the felling of timber for burning iron excepting in Sussex and parts of Kent and Surrey. This prohibition was extended

in 1581 and 1585 so as to exclude all timber "of the size of one foot at the stub," and prohibiting the erection of any new works in Surrey, Kent and Sussex, and here commences one of the great crises in the trade, viz., that due to the change from charcoal to pit coal fuel.

Up to this period the manufacture of raw iron was more perfectly understood on the Continent than in England. The Germans and the Swedes had developed the Blauofen and the Osmond furnace from the Catalan forge and made better iron than was made in England. But aided by the earlier necessity to use hard coal owing to the denudation of the forests and by the invention of the steam engine, the English now took the lead and retained it unto our own time through many changes which resulted in a complete revolution of the trade. Dud Dudley, in the seventeenth century, succeeded in making good iron by using pit and sea coal, but his invention was attacked by his rivals, his works were destroyed by floods, "to the great joy of many iron-masters," as he says. A staunch Royalist he saw a patent for making iron with pit coal given by Cromwell to another—though he had the satisfaction of seeing it fail—and on the restoration of Charles II he got no redress. So, in disaster and ruin, ended the first attempt to make iron with hard coal, and it was not until fifty years later, in 1713, that Abraham Darby succeeded in using coke in the blast furnace. Dudley had estimated that in 1660 300 furnaces were in blast, each making fifteen tons of iron per week during forty weeks in the year. This would give an output of 180,000 tons per annum. Owing to the scarcity of charcoal the number of furnaces in 1740 had fallen to fifty-nine making only 17,350 tons per annum. Dudley's figures may not be very accurate, but it is evident that during these eighty years the trade passed through a very severe crisis in

which the manufacture dwindled to very small dimensions.

The use of pit coal as coke in the blast furnace spread slowly, and iron had to be imported from abroad to make up the shortage in the home supply. Scrivenor gives the following table of imports and exports of iron:

	Imports.	Average tons.
1711 to 1718		15,642
1729 ,, 1735		25,501
1750 ,, 1755		34,072
1761 ,, 1776		48,980
	Exports.	
1711 to 1718		4,365
1729 ,, 1735		5,334

The imports of iron were from Sweden, Russia and the American colonies. The policy of Great Britain with regard to her colonies at this time had the effect of stimulating imports of raw iron. The idea at the back of the policy was that the colonies should supply us with raw material, that we should manufacture it into finished articles and return it to them in that form. To carry out this policy the importation of raw materials was encouraged and the manufacture of finished goods in the colonies was prohibited. Scrivenor says:—"In 1750 an Act, 23rd George II, was passed for encouraging the import of pig iron from the British Colonies in America. Every well-wisher to his country reflected with concern on the nature of the British trade with Sweden, from which country we imported more iron and steel than from all the other countries in Europe. For this article a great balance was paid in ready money, which the Swedes again expended in purchasing from the French and other mercantile states those necessaries and superfluities with which they might have been as cheaply furnished by Great Britain. In the

meantime, our Colonies were restricted by severe duties from taking advantage of their own produce in exchanging their iron for such commodities as they were under the necessity of procuring from their Mother Country. This restriction was not only a grievance upon our own settlements but also attended with manifest prejudice to the interests of Great Britain, annually drained of great sums, in favour of a nation from which we derived no advantage in return ; whereas, the iron imported from America must of necessity come in exchange for our own manufactures. The Committee having appointed a day for taking this affair into consideration, carefully examined into the state of the British commerce with Sweden, as well as into the accounts of iron imported from the plantations of America ; and a committee of the whole House having resolved, that the duties on American pig and bar iron should be repealed, a bill was brought in for that purpose. 'That pig iron, made in the British Colonies in America, may be imported duty free, and bar-iron into the port of London ; no bar-iron so imported to be carried coastwise, or to be landed at any other port, except for the use of His Majesty's dockyards ; and not to be carried beyond ten miles from London.' The Act, however, contained the following clause :—'That from and after the 24th day of June, 1750, no mill or other engine for slitting or rolling of iron, or any plating forge, to work with a tilt-hammer, or any furnace for making steel shall be erected, or, after such erection, continued in any of His Majesty's Colonies of America.'" Scrivenor goes on to show the results of this Act. The Governors of the colonies were ordered to make a return of the furnaces, etc., in their jurisdictions. This return showed that there were four mills for slitting or rolling, one not in use, eleven plating forges with tilting-hammers,

two not in use, and five steel furnaces, one not in use. The ironmasters petitioned against the bill on the ground that it would not lessen the import of Swedish iron, as that was brought in for purposes for which the British and American were unsuitable, and that the colonies would be able with their cheap fuel to undersell the British manufacturer to the ruin of thousands of labourers, who would have to emigrate, also that if the British iron manufacturer had to depend on supplies from America, which would be liable to be captured by enemies or lost at sea the trade would decay for want of materials. Against this view the iron-mongers and smiths "of the flourishing town of Birmingham in Warwickshire" petitioned that the iron-works of Great Britain did not make half enough material for the trade, and that if the colonies could supply the deficiency the Swedish importation would cease "and considerable sums of money be saved to the nation." They pointed out what was evident, that the importation from America would be no different in its effect from importation from elsewhere. The bill passed, and in 1756 the Society of Merchant Adventurers of Bristol petitioned for bar-iron to be allowed to be imported into any port as well as London. This was urged because great quantities of bar-iron were being brought in from Sweden, Russia, and other countries, and the curious old argument was again used that this was purchased with ready money, whereas if America sent it in it would be paid for by goods going out. The petition was opposed and a great controversy arose on what was considered a national affair. The opposers said that the fear of American imports had stopped the development of mining and iron-making, that the mines were inexhaustible and the growth of wood in coppices for iron-making utilised land which was otherwise

of no value and improved pasture land by the shade it afforded, that the destruction of the coppices would reduce the bark available for tanning, that neither British nor American iron could stop the import from Sweden because the latter only could be made into steel; the import from America, therefore, could only interfere with the British. The promoters replied to all this, and ultimately the bill was passed with a clause repealing a previous enactment which prohibited the conversion of wood and coppice into pasture or tillage. A curious comment on all this agitation and fuss is the list of exportations of iron from the American plantations which is as follows:

Years.	Tons.
1717 and 1718 together	7
1729 to 1735 average	2,111
1739 „ 1748 „	2,423
1750 „ 1755 „	3,305
1761 „ 1776 „	4,045

In 1776 the imports of iron into Great Britain from Russia were 34,000 tons, so that in spite of Acts of Parliament the "line of least resistance" was not deviated. There is little doubt that the irritation caused by these selfish trade regulations in the interests of British manufacturers and trade had much to do with the rebellion of the colonies.

In 1788 the quantity of iron made from coke was 48,200 tons, and from charcoal 13,100 tons. The effect on the trade of the substitution of coke for charcoal was to concentrate the manufacture of pig iron in those parts where coal was found. Thus the iron trade of Sussex and Kent disappeared and that of Staffordshire, South Wales and Yorkshire greatly increased. In Scotland the manufacture of iron from charcoal appears to have been on a very small scale, as the first furnace was erected in 1750 and in 1788 two

furnaces were blowing with charcoal and producing 1,400 tons a year. But the use of coke as fuel and the discovery in 1801 of the blackband seam of ironstone laid the foundation upon which the great iron trade of Scotland has been built.

While this great change in the iron trade was taking place the invention of cast steel by Huntsman, in 1770, brought about an equally great change in steel, for by it the makers of fine Sheffield goods were provided with an ideal material for the manufacture of the finest cutlery. Huntsman was a watchmaker, who took up the question of improving the quality of steel. Whether he knew or learnt anything of the method of making Wootz steel or not it is impossible to say, but his invention was very much on the same lines as those by which steel had been produced for centuries in Eastern countries.

The early years of the nineteenth century saw the completion of the change from charcoal to coke fuel in this country, and in 1806 only eleven charcoal furnaces remained in blast, making but 7,800 tons out of a total make of 258,206 tons of pig iron. The expansion of the home trade was greatly assisted by the increase in the price of foreign iron. In 1796 the price of Russian iron increased by about 30 per cent. because apparently the Russians thought our market was at their mercy. The import duty was increased by £1 per ton between 1796 and 1798, and another 10 per cent. rise in the price took place in 1800, bringing the increase since 1795 to £10 per ton. The duty on pig iron in 1780 was 56s. per ton, and the price of Russian iron delivered in England was £17 per ton, and of Swedish iron £18 10s. per ton. The advance of £10 would therefore bring up the price of Russian iron to £27 per ton. The price of English iron in 1799 was £16 per ton, in 1803 £19 per ton, and shortly afterwards £14 per ton.

Scrivenor gives the following list of import duties charged on bar-iron.

1782 to 1795	£2	16	2	per ton	
1796	3	1	9	,,	
1797	3	4	7	,,	
1798 to 1802	3	15	5	,,	
1803	4	4	4½	,,	
1804	4	17	1	,,	
1805	5	1	0	,,	
1806 to 1808	5	7	5¾	,,	
1809 ,, 1812	5	9	10	,,	
1813 ,, 1818	6	9	10	,,	
1819 ,, 1825	6	10	0	,,	in British ships
and	7	18	6	,,	,, Foreign ,,

In 1825 the duties on iron and steel were reduced as follows:

		Former Duty.			New Duty.		
Iron.	In bars unwrought from British Colonies per ton	£1	2	2	£0	2	6
	In bars from elsewhere . .	6	10	0	1	10	0
	Rods slit or hammered less than ¾ inch square per cwt.	1	0	0	0	5	0
	Cast, per £100 value . .	20	0	0	10	0	0
	Old broken and cast-iron p. ton	0	17	6	0	12	0
	Pig iron ,,	0	17	6	0	10	0
	,, from American Colonies ,,	0	8	0	0	1	3
	Wrought, not otherwise described, per £100 in value .	50	0	0	20	0	0
	Wire, per cwt.	5	18	9	1	0	0
	Hoops ,, ...	1	3	9	1	3	9
Steel,	or any manufacture of Steel, per £100 value . . .	50	0	0	20	0	0

The arguments used in favour of these reductions were that the supply of iron in the country was inadequate to the demand, that foreign orders for iron had to be refused because the manufacturers here could not afford to supply the goods at a price which the foreign customer could pay and foreign trade was thus being lost, that the duties were prohibitory and therefore the exchequer received no income from them.

But no import duties now mattered because the natural advantages of fuel and iron-stone which Great Britain possessed enabled her to overcome all competition in her own land and to extend her trade to other countries in spite of hostile tariffs. The output of iron increased from 258,000 tons in 1806 to 368,000 tons in 1820, 690,000 tons in 1827, and a million tons in 1835, and the imports dwindled to 17,015 tons on the average from 1823 to 1830.

It is interesting to look back at this point when Great Britain became self-supplying in the matter of iron to the fluctuations in the imports in earlier years. As early as 1216 the home supply was so small that importations had to be made from the Continent, but the home production had so largely increased by 1483 that importations were forbidden, and late in the sixteenth century iron in the form of cannon was exported. This trade led to the complaint that Spain armed her ships with English cannon to fight against us, and consequently the export was forbidden. In the seventeenth century the civil war paralysed the industry, and in the eighteenth the exhaustion of the forests led to recourse again being had to the Continent for supplies. But now came the change which put England in the leading position. While the Continent, with its large supplies of timber, continued to use charcoal fuel the English works were driven to use coke. As experience with coke was gained it was found to be much cheaper than charcoal and the output of iron much greater. The abundant supply of coal and its proximity to the ore gave Great Britain a great advantage over the continental nations. Germany, her great competitor in modern times, up to the close of the Napoleonic wars in 1815, was constantly devastated by hostile armies which destroyed all industry for the time being, and

America had not begun to develop her resources. Great Britain, with peace within her own borders, took advantage of the opportunity to develop her iron industry which the possession of coal and iron-stone in vast quantity enabled her to do. The lead which she was thus enabled to establish over her continental competitors was increased by the early development of railways, and it was not until 1890 that she had to take second place owing to the growth of the trade in the United States with its huge stores of iron ore, its great territory and large population. In 1903 Germany also passed her owing to the development of the Bessemer basic steel process for which her ores are specially suitable.

We in Great Britain may regret that we no longer hold the blue ribbon for iron production, but it is not a position which any action on our part could possibly have altered, and it is wisdom to accept the inevitable without getting angry. If we could have treated the United States as the American colonies were treated in the Georgian days and prohibited them from making any manufactured iron, or setting up any plant for doing so, then the American output of iron would have kept down, or if we could have suppressed the Thomas-Gilchrist process of steel-making, Germany could not possibly have become a great maker of steel, but under no circumstances was it possible to do either of these things. We cannot say to the United States, "You shall not develop your minerals without our permission"; nor to Germany, "We will not allow you to use the Basic process"; nor to nature, "You had no right to provide these countries with more iron ore than you gave to us." Only very foolish people would take up such a position, for it is certain that in the progress of nations, all other things being equal, that country with

the greatest natural resources will make the largest quantity of goods from natural products. Great Britain can no more hope to rival America in the production of iron than the Isle of Wight can hope to rival England in the growth of corn, nor is it to be expected that the 208,627 square miles and sixty-one million inhabitants of Germany will not require more iron than the 121,305 square miles and forty-four million inhabitants of Great Britain.

From 1836 to 1860 the British iron trade grew at a great rate, and the output of pig iron reached 3,826,752 tons in the latter year. Railways and manufactures of all kinds called for an ever-increasing quantity. The discovery of the main seam of Cleveland iron-stone led to the establishment of great works on the banks of the Tees, which were able not only to supply the home market with pig iron but to export it to the Continent, where a great trade was built up. It is to be borne in mind that the whole of this pig iron in the home market was used for making malleable iron in the puddling furnace or for castings. The rail and plate trades were principally carried on in Staffordshire, on the North East coast and in South Wales. The most successful of these was that of Mr. Danks, which has been referred to. The success of Bessemer's new process, however, put a stop to all attempts to improve the puddling furnace, which for the manufacture of rails and plates was practically abandoned. The transit from the puddling furnace to the Bessemer converter for the manufacture of rails began in 1873 and was completed by about 1879, and in the case of plates it lasted from about 1880 to 1890. In South Wales great distress was caused among the workmen who were dismissed as the puddling furnaces were put out, no less than 734 out of 1,251 of these

being extinguished between 1873 and 1880. In 1890 there were only eighty-three in operation, and in 1906 the number in North and South Wales together had dwindled to twenty.

The great development of the iron and steel trade in modern times began with the invention of the Bessemer process in 1855. Up to the time when Bessemer steel was first made in 1860 steel was only known as the raw material for the cutlery and similar fine trades. It was very costly, being made by an expensive process from expensive imported material. In 1841 Russian and Swedish bar-iron imported by Hull merchants cost from £20 to £35 per ton at Sheffield, the price being artificially maintained by the restriction of exportation by the Swedish Government. All other requirements for railways, shipbuilding, machinery, pipes, etc., were met by iron made in the puddling furnace or the cupola. The discovery of mild steel, as it has come to be called, changed all that, and although the foundry trade has altered little, the manufacture of malleable iron has shrunk to comparatively small dimensions.

CHAPTER XI

THE IRON TRADE OF VARIOUS COUNTRIES

GREAT BRITAIN

THE two outstanding features of the iron trade of Great Britain, after the invention of hot blast by Neilson in 1829, are the rise of the Scotch iron trade and the discovery of the main seam of Cleveland iron-stone in May, 1850. The earliest reference to iron-making in Scotland is in an Act of the Scottish Parliament in 1686, where "the trade of founding, lately brought into the kingdom by John Meikle for casting of balls, cannons, and such other useful instruments," is mentioned. Two charcoal furnaces were erected in 1750, and in 1759 the Carron ironworks near Falkirk were established. These were evidently intended from their name for the manufacture of "carronades," a small cannon used for close fighting on board ships. In 1760 the make of pig iron in Scotland was 1,500 tons, which in 1788 increased to 7,000 tons, and in 1796 to 16,086 tons. In 1801 the discovery of the Blackband seam of iron-stone laid the foundation for the great trade which grew up subsequently, but it was not until after Neilson's discovery of the hot blast that the output of iron increased largely. In 1806 the make of iron was 20,240 tons; in 1820, 20,000 tons; in 1823, 24,500 tons; in 1827, 36,000 tons; in 1829, 29,000 tons; in 1830, 37,500 tons; and in 1836, 75,000 tons. Now began the great development out of all proportion to any increase in other parts of the country. In 1839, 196,960 tons were made; in

1843, 280,000; in 1845, 475,000; in 1846, 580,000; in 1849, 690,000; in 1851, 770,000; in 1855, 820,000; in 1858, 980,000; and in 1860, one million tons. While from 1830 to 1860 the Scotch make of iron increased from 37,500 to 1,000,000 tons, or more than twenty-five times, the total make of Great Britain only increased from 678,417 tons to 3,826,752 tons, or a little more than five and a half times. By 1860 the trade had been developed to its full capacity and as the Blackband iron-stone was exhausted foreign ore was imported to take its place. In 1906 the total quantity of iron ore mined was 875,358 tons, which at two and a half tons per ton of iron would give only 350,143 tons of iron, whereas the iron made amounted to 1,451,068 tons.

The increase in the output of iron was not all disposed of in this country. The cheapening of the cost through the use of coke and hot blast enabled the iron to be put on the foreign markets at a price with which the charcoal-made iron of the Continent could not compete. While the imports of iron declined and were probably no more than were necessary for the manufacture of fine steel in Sheffield the exports bounded upward as the following table from Scrivenor's History shows:

1796 to 1805	average	29,446 tons
1806 ,, 1808	,,	41,593 ,,
1812		57,791 ,,
1814		57,019 ,,
1815 ,, 1822	,,	91,772 ,,
1823 ,, 1830	,,	103,439 ,,
1830 ,, 1834	,,	157,317 ,,
1835 ,, 1839	,,	236,139 ,,
[1]1840 ,, 1844	,,	381,254 ,,
[1]1845 ,, 1849	,,	534,120 ,,
[1]1850		783,482 ,,
[1]1851		919,479 ,,
[1]1852		1,035,884 ,,

[1] including unwrought steel.

The development of railways in the thirties no doubt stimulated the production of iron in Scotland, and when the first rush was over in the forties the price fell to below 40s. per ton. An upward movement set in until 1852 when prices again fell, this time to 35s. 6d. per ton, which was the lowest price ever touched. The importance of the foreign trade may be gauged by the fact that in 1843, with a make of 280,000 the foreign exports reached 106,605 tons. It was this export trade both to home and foreign ports which distinguished the Scotch market and which later became the characteristic of the Cleveland trade. The peculiar value of the Scotch iron was recognised everywhere and it became the standard iron for foundry work. The activity due to the great increase in the output, the opening up of foreign connections, and the great irregularity in prices led to the establishment of the Scotch iron market and the warrant store which will require a chapter to themselves.

When the Scotch iron output from native ores had reached its maximum in the early fifties the introduction of Cleveland iron raised up a formidable rival to it for foreign trade. The new iron was cheaper and the cost of shipping it to the Continent less than the Scotch. The consequence was that it quickly got a foothold in continental markets, and although it was not of such good quality it answered admirably as a mixture and for heavy rough work was better. But it was not only the foreigners who appreciated the advantages of Cleveland iron. The Scotch founders themselves, obtaining it at a very low cost of carriage through the port of Grangemouth, began to use it to mix with their own iron and the Scotch market became the most important one for the Cleveland ironmasters. As the output of Scotch foundry iron dwindled through the working out of the

iron-stone seam the output of Cleveland iron increased until it became the principal foundry iron of the world, finding its way to every market from Norway to the Cape, and from Holland to San Francisco.

The following are representative analyses of Scotch and Cleveland iron :

Scotch.	No. 1.	No. 3.
Carbon graphitic	3.10	3.75
,, combined	.25	.50
Silicon	2.45	2.67
Sulphur	.01	.03
Phosphorus	.82	.80
Manganese	1.60	.40
Iron by difference	91.77	90.85

Cleveland	No. 1.	No. 3.	No. 4 fy.	No. 4 forge.
Carbon graphitic	3.30	3.01	2.80	3.00
,, Combined	.15	.27	.48	.62
Silicon	2.90	2.80	2.31	1.53
Sulphur	.03	.04	.08	.14
Phosphorus	1.52	1.50	1.55	1.50
Manganese	.60	.58	.50	.45
Iron by difference	91.50	91.80	92.28	92.76

When the production of mild steel began to take the place of malleable iron in the manufacture of rails, plates, bars, etc., the finished iron trade of Cleveland was reduced to small dimensions, but the district did not suffer so much as South Wales, as the importation of foreign ore was begun for making hematite iron. At this time, 1860 to 1870, the Continent and America were supplied with pig iron largely from the Scotch and Cleveland furnaces, and it was not until the development of the manufacture in America increased so much that they could supply their own wants, and until the invention of the Thomas-Gilchrist process enabled Germany to commence the development of her enormous ore resources in Elsass-Lothringen, that Great Britain ceased to be the iron centre of the world. And although the output of British iron and steel is now smaller

than American and German, it is perhaps hardly accurate to say that Great Britain is not still the centre of the trade, for the home markets of America and Germany absorb such a large proportion of the output of those countries that they supply a smaller proportion to the outside world than does Great Britain.

GERMANY

The early history of iron-making in Germany is very much on the same lines as that of England. The Catalan forge developed into the Stückofen and the Blauofen, and it is probable that the first cast-iron was made in Germany. The Germans and the French were noted at a very early period for the excellence of their iron castings. The blast furnace, working with charcoal, was invented in Siegerland in 1500 and was introduced into England in 1534. The first furnace using coke was built at Gleiwitz, in Upper Silesia in 1796. Up to this period Germany was one of the most advanced nations of Europe in the manufacture of iron, producing more pig iron than was required in the country itself and exporting considerable quantities to Great Britain. Scrivenor says that from the Conquest to the death of King John, and also in the fourteenth and fifteenth centuries, iron and steel were imported into England from Germany and other countries. The use of coke in the blast furnace was not adopted in German furnaces until nearly eighty years after it was first used in England, principally because there was no dearth of charcoal in Germany, and also because coal was not too plentiful. The use of coke as fuel put Germany at a disadvantage to Great Britain in the manufacture of iron because her coal was not so suitable for producing coke, it was not found in such large quantities, and it was not so conveniently situated

in reference to the ore. The ore also of the coal formations was not found in the same abundance as in Scotland and Staffordshire, and there was little ore to compare with the rich hematite of Cumberland. On the other hand, brown ores were plentiful, but the ores generally were at considerable distances from the coal, thus increasing materially the cost of making iron. There are no early records of the output of iron, but in 1837, in Prussia, the make was 99,000 tons of pig iron. The output increased very gradually until, in 1879, it reached 1,639,676 tons in Prussia and 2,100,294 in the German Empire. The largest proportion of this was made in the Westphalian district where coal and iron ore were the nearest together and where foreign ore could be imported by the Rhine at the least cost. The output of steel in that year in Prussia was 464,642 tons by the Bessemer converter, 56,827 tons by the open hearth, and 1,273 tons by other apparatus, in all, 522,742 tons. In making this, 356,311 tons of German and 106,878 tons of foreign pig iron were used. There did not seem at this time to be much probability that Germany would become a great iron and steel country. Her ores were not suitable for making steel by the only cheap process then known, they were far from the coal and separated by land so that cheap water carriage was not available. But now came the transformation scene. The Thomas-Gilchrist process was invented and Germany found herself with a great advantage over every other country in that she possessed in the Minette ores of Luxemburg and Lothringen an ideal mineral for the new process in quantities which could not be calculated. Not only did she possess the mineral but she also had the men with brains and training to carry out the process. Her admirable technical schools turned out yearly a number of young men with scientific

knowledge who were set to work to utilise the new method of steel-making. Works sprang up, difficulties were overcome and a great ambition took hold of those in the trade to push German manufactures of iron and steel into the forefront of the world's trade. They succeeded so well that in 1900 they made more iron than was made in Great Britain, and in 1910 the output of pig iron was 14,559,670 tons. To show how much Germany owes to the basic processes of steel-making it is only necessary to say that in 1908, out of 11,078,660 tons of steel made, no less than 10,480,349 tons were basic steel and only 598,311 tons were acid steel. The quantity of acid steel has therefore practically not increased since 1879. The basic processes have enabled Germany to take up a great position in the iron and steel world in spite of the difficulties of inferior coal and heavy transport charges. She has been helped in this struggle by the heavy import duties which have prevented other countries competing against her in her home market. She has thus been able to charge prices to her home customers which have left her a very handsome profit, and all internal competition of her own manufacturers has been eliminated by the formation of trusts or syndicates. The profit on her home trade has tempted her to build works and sell the surplus in outside markets at any price that it will fetch. The foreigners have thus been able to take advantage of her cheap material while her home people have been charged full prices. The high home prices have also resulted in furnaces being built in such places as Lübeck and Stettin, far from all native coal or ore, and fed with imported ore and imported coal. Fed artificially by protective duties and hedged round with syndicates, the iron and steel trades of Germany are flourishing, and will probably succeed in keeping out all foreign

competitive manufactures, and in capturing a great part of the trade of the nearest continental countries. So long as the internal general trade of the country increases and takes its full share of the increased make of iron at a large profit to the maker the prosperity will continue, but when, as in time it will, the make of iron increases at a greater rate than the country can absorb it, a larger proportion will have to be placed abroad at a disadvantage, and when the total disadvantage of the foreign trade surpasses the total advantage of the home trade a crisis will come which will not be overcome without grave difficulties if not disaster. At present there is no sign of such difficulties, the steel trade of the world is expanding at a great rate and German manufacturers are probably not only making a very handsome profit on their home trade in steel but a moderate one on their foreign trade. But a weak or unstable foundation will in time surely have its effect on the superstructure and bring about a collapse in the end. Those who take a broad view of German trade cannot ignore the tendency of the present policy to encourage production without regard to consumption, and they view with apprehension the inevitable result.

THE UNITED STATES OF AMERICA

It is fairly well established that the aboriginal inhabitants of the American Continent were unacquainted with the use of iron. The highly civilised people of Peru and Mexico used copper only, and the Indians of North America did not use iron until it was introduced by Europeans. This ignorance of iron is very striking evidence of the early period at which America was first inhabited, for it is very improbable that any people who once knew of iron would ever entirely lose that knowledge. The history of iron in America, therefore,

begins with the invasion of the Europeans who brought with them their knowledge of the Catalan forge. Iron ore was first discovered in 1585 by Sir Walter Raleigh's expedition on Roanoke Island. In 1608 a quantity of ore was shipped to England and smelted, and seventeen tons of metal produced. This was the first iron made from American ore. The first attempt to establish ironworks in Virginia ended disastrously and the first works put down were in the province of Massachusetts Bay in 1643. The industry flourished and was gradually extended to other provinces, the abundance of timber available for charcoal being of great advantage. It has already been pointed out that the British Government interfered with the development of the trade by prohibiting the use of mills and forges for making finished iron, compelling the trade to be restricted to the manufacture of pig iron for export to England, except such quantities as could be used in the forges and mills already in work. After the War of Independence heavy duties were put on imported iron, and the immigration of skilled artisans and workpeople from Europe was encouraged. In 1810 the annual value of iron and its manufactures was estimated at twelve to fifteen million dollars, and the value of imported iron at four million dollars. Heavy duties continued to be levied for the purpose of protecting the native works, and a great controversy arose between 1828 and 1833 upon these duties. The tariff had been altered as follows:

	1818 dols.		1824 dols.		1828 dols.	
Iron in bars, rolled	1·50	per cwt.	1·50	per cwt.	37·0	per ton.
,, ,, not rolled	·75	,,	·90	,,	·1	per lb.
Pig iron	·50	,,	·50	,,	·62½	per cwt.

The duties charged were compared unfavourably with those of Great Britain, which were 6 dol. 66 cts. for

bar-iron and 2 dol. 22 cts. for pig iron per ton, and it was argued that the heavy American duties tended to perpetuate the industrial ascendency of Great Britain. The result of the agitation was that in 1833 the duty on pig iron was reduced to 50 cts. per cwt., and on bar-iron to 30 dols. per ton. In 1842 these duties were reduced to 17 dols. for hammered and 25 dols. for rolled iron and 9 dols. for pig iron.

The following figures of imports of British iron are given by Scrivenor :

Years.		Tons.
1815 to 1819	average	15,097
1820 ,, 1824	,,	11,832
1825 ,, 1829	,,	17,491
1830 ,, 1834	,,	43,630
1835 ,, 1839	,,	74,346
1840 ,, 1844	,,	63,099
1845 ,, 1849	,,	181,662
1850		367,862
1851		464,559
1852		501,158

In 1850 the quantity of pig iron made in the States was 564,755 tons, so that 60 per cent. of the iron used was home made and 40 per cent. imported. From 1850 the manufacture of iron rapidly increased, so that in 1860 the pig iron output was 821,223 tons, in 1870 1,665,178 tons, in 1880, 3,835,191 tons, in 1890, 9,202,703 tons, in 1900, 13,734,860 tons, and in 1910 it was 27,298,545 tons. The production has therefore been about doubled every eleven years on the average. No other country in the world can show such a development as this at any period of its history. Germany comes nearest with about half the production at each decade, but in the earlier years before 1870 the district of Elsass-Lothringen, which now produces a large quantity was not included.

The American expansion has been brought about

by the development of the country and by the possession of great resources for iron-making in the Lake Superior ores and Connelsville coke. The enterprise and organisation necessary for bringing these materials together gave an admirable opportunity for the display of American energy and ability. The transport of ore across the Lakes and its conveyance to the furnaces at Pittsburg and other places is a triumph of engineering skill and business capacity which has no parallel in any other part of the world.

From time to time the output of iron in the States has exceeded the demand, and the ironmaster there has then had to consider whether he should dispose of the surplus in outside markets or reduce his make. The Pittsburg furnaces are too far from tide-water to admit of any iron from them being shipped oversea, but the Southern furnaces in Alabama are able to put iron f.o.b. at Pensacola for about a dollar per ton. Pensacola is a Cotton port, and there are, therefore, opportunities of shipping iron in ships taking cotton to Europe which are not loading their full carrying weight. In this way it has been possible to ship pig iron to Northern European ports such as Bremen, Hamburg, Rotterdam, etc., and to Mediterranean ports such as Genoa, Savona, etc., at a cost which would compete with British iron. But the geographical position of the American works generally is such that any serious competition in outside markets is not to be looked for. The Canadian markets, on the other hand, except those on the St. Lawrence river, are open to American competition, and as Canada has up to the present not developed any ore or coal-fields which will provide for her rapidly increasing population it would appear to be in her interest commercially to cultivate trade with her best market, which over a great extent of her territory is

that of the States. In the Western States the absence of coal and ore in large quantities renders it difficult to establish the manufacture of iron as a national industry, and supplies of iron are obtained from the Eastern States. Imports into Western ports such as San Francisco and Seattle are received from Europe, but recently the Chinese works have sent in considerable quantities. It is probable that as the Chinese iron trade develops the requirements of the Western States of America will be largely supplied by that market.

FRANCE

The early history of iron-making in France differs in no respect from that of other parts of the continent of Europe. The change from charcoal to hard coal or coke fuel took place later than in Great Britain, and in 1836 no less than 593,855 tons of charcoal were used in the manufacture of iron. The price of charcoal rose in about six years from 1822 from 18 fcs. to 37½ fcs. per banne (50 cub. feet), in the Meuse, and from 16 fcs. to 23½ fcs. in the Côte d'Or, and the result was a gradual replacement of charcoal by coke. The French iron industry suffers from the coal and ore supplies being far apart. The coal supply is mainly in the Nord and Pas-de-Calais districts. The ore is principally in the Nancy and Longwy districts. The earliest records show that the output of pig iron in 1800 was 60,000 tons. The output in 1909 was 3,488,652 tons. The loss of Alsace-Lorraine to the Germans in 1870 curtailed the extent of the ore-field, but there are still in the district near Metz in France immense quantities of Minette ore which are gradually being opened out.

The iron trade in France has been the subject of many legislative acts. During the Napoleonic period

the demand for iron for war purposes increased greatly, and when peace came, after 1815, the manufacturers found themselves in difficulties because no more implements of warfare were required. They laid the blame on the imports of iron which came in from Great Britain and elsewhere, and therefore petitioned the Government to prohibit the importation of iron. The Government therefore raised the import duty in 1822 from 22 fcs. per 1,000 kilos. (about 17s. 6d. per ton) to 150 fcs. (£6 per ton). Even this was not found sufficient, and although strong arguments were used in favour of following the example England was setting of releasing trade from the incubus of protective duties the duty was raised to 250 fcs. per 1,000 kilos., but the iron from England only was charged this rate, that from Sweden, Spain and Holland paying only the lower rate of 150 fcs. This was still not altogether effective, for though 13,133 tons of bar-iron were imported in 1821, in 1822, 4,800 tons were imported. A commission in 1829 recommended that the duties should be continued for five years and then reduced one-fifth, and after another five years the Government should again consider the question. The Government accepted the recommendation but made the reduction only one-tenth. In 1853 the duty on pig iron was 50 fcs. per 1,000 kilos. in French vessels and 10 per cent. more in foreign vessels. In 1855 this duty was reduced to 40 fcs. and subsequent changes have reduced it to its present amount of 15 fcs. per ton of 1,000 kilos.

BELGIUM

Belgium, possessing a larger supply of fuel than France, has been able to establish the iron trade as one of the principal industries of the country. One authority says that it was in Belgium that the first cast-iron

was made, and that in 1560 there were thirty-five furnaces and eighty-five forges in the province of Namur. But it was not until after the release from the burden of war, after Waterloo, that the trade became well established. John Cockerill, an Englishman, is regarded as the founder of the modern trade in iron in Belgium. In 1817 he was invited by the King to establish works near Liège and received a large subsidy for that purpose on the condition that he would allow the ironmasters of Liège and Namur to go to his works and learn the principles of and latest improvements in the art. Thus were begun the great works at Seraing, one of the most important in Europe. In 1823 the first coke blast furnace was put up there, and the improvements in iron and steel-making which originated in Great Britain were quickly adopted by the Belgians. The native iron-stone of the country was gradually worked out and then the oolitic ore of Luxemburg was drawn on and is now used almost exclusively. There are no early statistics of the trade. The make of pig iron was 52,000 tons in 1830, which increased to 1,775,015 in 1910.

AUSTRIA-HUNGARY

The Austrian iron trade is a very old one. The steel of Styria was famous in the Middle Ages and the ore worked in that district is to-day the chief source of the manufacture of iron. The coal of the country is not of high quality and consequently the manufacture of iron is carried on under disadvantages. But the quantity is large, and as the manufacture of iron is protected artificially by means of an import duty, and also naturally by heavy land or river carriage to the interior, the trade is a very profitable one to the manufacturers. The position of Austria-Hungary with little seaboard and difficult means of communication

with the outside world renders it impossible for any competitive trade to be established with distant lands. On the whole, she will remain rather a buyer of iron from outside than a seller, and her position as a competitor in the world's market may therefore be disregarded.

RUSSIA

The manufacture of high-class iron was at one time a great industry in Russia and she competed with Sweden for the English trade in the eighteenth century. Mining is said to have been practised in Siberia before all records. Peter the Great encouraged the trade in iron, and mining was begun in many districts. The output of iron increased and a large foreign trade was built up. At the end of the eighteenth century the trade with Great Britain had increased to such an extent that the Russians concluded we could not do without their iron. They therefore increased their price by degrees from about £9 10s. per ton in 1770 to about £27 per ton in 1798. The British, however, by the use of coke managed to increase their output of iron and do without the Russian supply. The output of pig iron in Russia has increased from about 250,000 tons in 1850 to 2,825,978 tons in 1909. This quantity is, however, a mere bagatelle when the immense area and mineral resources of the country are considered. Russia is still an undeveloped country not far removed from the crude Northern civilisation of the seventeenth century, and when she is able to obtain some sort of reasonable government and the undoubted ability of her people has some opportunity of expressing itself she will take her place among the great producing countries of the world. How long that time will be delayed depends on the wisdom or unwisdom of her political rulers.

QUARRYING IRON ORE IN SOUTHERN RUSSIA

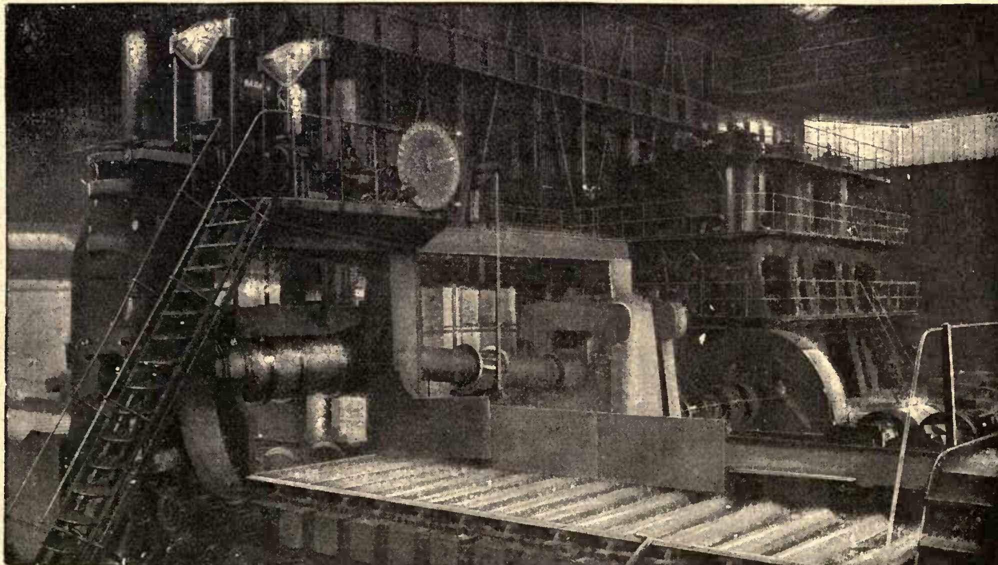
SWEDEN

As the source of the highest class of iron from which the best steel was made Sweden has always taken a high place among iron-making countries. The iron mine of Dannemora was discovered in 1448, and it has been worked almost continuously since then. This ore is a magnetic oxide of iron free from phosphorus and low in sulphur with about 6 per cent. of lime and 10 per cent. of silica. From it the best Swedish iron was made and exported to all parts. The shortage of timber for charcoal-making limited the production of iron, and although possessing immense stores of iron ore, because of the lack of fuel Sweden cannot become a great iron-making country under present conditions. In 1803 the output of iron was estimated at 48,000 tons, in 1812 it had been increased to about 60,000 tons. In 1850 the output was 141,000; in 1860, 185,000; in 1870, 300,000; in 1880, 405,000; in 1890, 456,000; in 1900, 526,000; and in 1909, 443,000, after being 603,000 in 1907. The entire absence of coal renders the making of pig iron with coke impossible, and only high-class charcoal iron, such as Sheffield uses for her fine steel trade, is now produced, with the exception of a small quantity made electrically. It is just possible that the development of the electric furnace will alter the position of Sweden in the iron world. She has in her numerous waterfalls a source of cheap power which, if used for the production of electricity, may make the manufacture of iron on a large scale feasible. This, however, is not at present a practicable proposition.

THE WORLD POSITION

The present condition of the iron and steel trades of the world is a very interesting one. If the development

of the manufacture, which has been going on during the last ten to twenty years at such a great rate in Germany and America has come to an end the position may be fairly assessed, but if the output in those two countries is to be still further increased no one can predict the result except to say that there will be trouble. Taking the position as it is to-day we have Germany producing fourteen to fifteen million tons of pig iron and other furnaces building to make probably a million more; we have America with plant capable of turning out about thirty-three million tons but only making twenty five to twenty-six millions because the remainder is not wanted. After these comes Great Britain with about ten million tons. America has shown that she will not make pig iron unless it is wanted. Germany has made as much pig iron as possible and turned it into steel to be sold at all hazards. Her own home market, which is heavily protected, is not large enough to consume her output and she has to look to foreign trade to take up the surplus, which is very large. The great profits which she makes upon her home trade enable her to sell outside at small profits, or even at a loss, but naturally the larger quantity she has to dispose of in this way the worse off she is. She is handicapped by being far from the sea, but her cheapness of manufacture gives her some compensation for this. Unlike America with its immense territories westward, capable of fuller development, which will call for all the iron and steel she produces, Germany has no natural outlet for any increased quantity, except that due to the normal increase of her population. Great Britain has long been in that position, but Germany has not yet got used to it, and the difference between the price she charges to her own people at home and that at which she sells to the foreigner will always be a source of



40″ COGGING MILL WITH 18,000 H.P. ENGINES

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criticism. Until the expansion of the world's markets takes up the increased production freely the struggle will lie between Germany and Great Britain principally, though Belgium will have a hand in it. Great Britain has the advantage of being on tide-water with her works and of having splendid supplies of coal and coke, besides on the whole making a better class product; she has the disadvantage of a higher cost of manufacture in wages, dearer management, and in many cases less modern works. On the whole, Great Britain, if it comes to a push, can hold her own in the markets of the world, and the keen competition of Germany and Belgium will be an advantage to her if it presses her into keener management, less wasteful methods, more economy and better organisation than in many cases are shown at her works.

CHAPTER XII

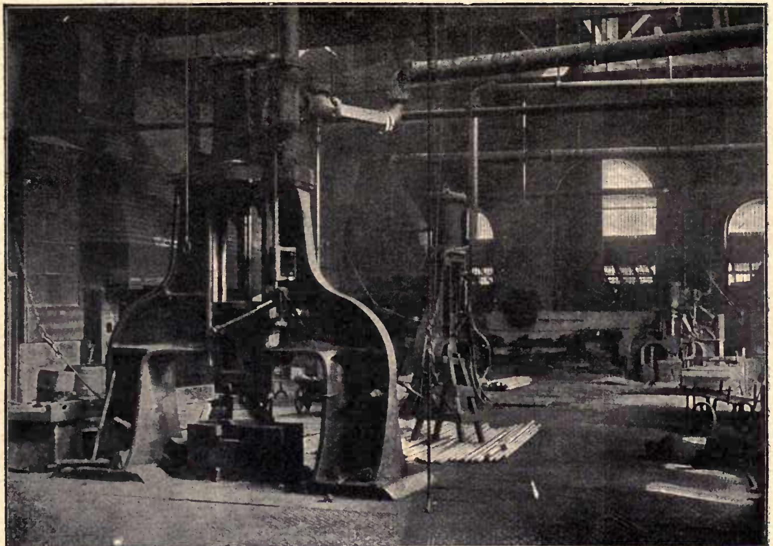
THE WARRANT MARKET

THE difficulty in which the Scotch ironmasters found themselves in the early fifties when the price of their iron fell below 40s. per ton with no demand for a considerable portion of their output was met by an endeavour to raise money upon their stocks. For this purpose they sold "scrip" to whoever would buy. This scrip was simply a promise to deliver a certain quantity of iron to the bearer on presentation of the scrip and on payment of the accrued charges for storage. When this had gone on for some time the makers found that there was some hesitation on the part of the buyers to accept scrip with only the security of the maker's word that the iron existed. It left the door open to any firm in financial difficulties to raise money on scrip for iron which did not exist. In order to get over this difficulty and provide a security beyond question, they arranged to deliver the iron into a store owned and managed by an independent firm who should issue "warrants," undertaking to deliver the iron to the bearer of them. Thus began the system which has played such an important part in the iron markets of the world during the last fifty years. The Railway Companies have from time to time acted as storekeepers, but the principal firm whose warrants have become a marketable security all the world over is that of Messrs. Connal & Co., Ltd., of Glasgow and Middlesbrough. The warrants for Scotch iron were for 300 tons No. 1 and 200 tons No. 3, and for Cleveland iron 500 tons No. 3. The storage charge is one penny per ton per

month and the cost of holding a warrant was therefore the interest on the money invested in it and the rent or storage charge. These two items, with money at 5 per cent. interest and iron at 50s. per ton, would come to 3½d. per ton per month. The "contango," therefore, for warrants for delivery a month forward is usually about 3d. per ton, though with high prices and dear money it has been as high as 7d. per ton. The result of making the warrants a negotiable security was that the banks were willing to advance money upon them up to within a few shillings of their market value, and this facility for borrowing money on them enabled the dealers to hold a large number at a merely nominal cost. An active trade in these warrants was at once set up and was the cause of the establishment of the Glasgow Iron Market, which for the last sixty years has been the centre of the commercial world in iron, dominating all other markets. The Scotch warrant store gradually increased until, in 1888, it contained over a million tons of pig iron.

The ironmasters found that what had been a relief and a convenience to them, became when well established a whip for their backs. They had found an exceedingly easy way of selling their iron, but they had parted with the control of the market, and put that control into the hands of those whose interests were the opposite of their own. When the ironmaster previously wanted to sell his iron he knew that save for the competition of other makers situated like himself he had no fear of the orders being taken from him, but now, when orders were going, his own iron in the store was offered against him by the warrant holders. So he found himself tied hand and foot to the warrant market. If he could have controlled that market in any way he still might have had some influence in the sale of the iron he was making, but this was impossible.

For every ton of his iron that he could offer probably four or five tons existed in the store, to be brought out at once if he attempted to get more than the warrant quotation. His only source of comfort was the fact that it is the supply and demand which ultimately rules the price and the supply is that quantity which can be obtained at a given price on a given day. Alter the price and the supply is immediately altered. Raise the price and the supply increases because holders of iron as warrants are willing to sell more, lower it and the supply decreases. Thus, in spite of the loss of the market control, he managed to get along until he found that the warrant holders not only controlled the market but manipulated it also and that to his disadvantage. It was probably more than could reasonably be expected of dealers in a keen market in which profits were cut to the smallest fraction not to turn the market in their favour when they had the means in their own hands. For instance, when a manufacturer came into the market for a big " line," was it not too much for human fallibility to refrain from putting up the price by buying warrants in the " Ring " and bidding high ? And when the manufacturer had bought could any objection be made to selling warrants at a low price and then covering the sale to the manufacturer at a handsome profit. When one or two thousand tons judiciously bought at say sixpence or a shilling advance will land a ten thousand ton order at the top price, and one or two thousand tons sold equally judiciously will pull the price down to its old level the profit is not to be sneezed at. Of course it is essential to keep the buyer in the dark, and therefore the transactions must be well covered up by market rumours and reports to account for the movements in the price. The influence which the middleman by his command of warrants obtained was contrary to the interests of both manufacturer and



TILTING HAMMERS FOR HAMMERING-OUT STEEL BARS

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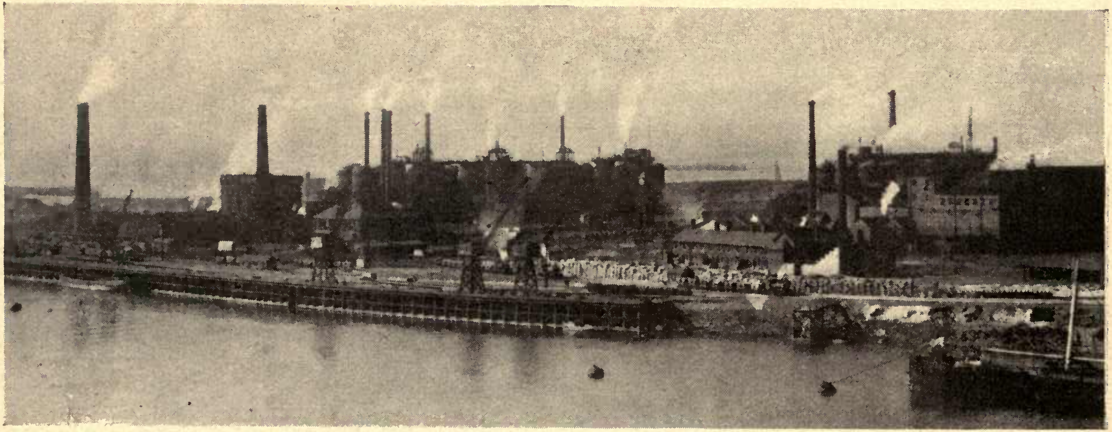
consumer. The manufacturer wanted to sell at a high price but the middleman wanted to buy at a low one, the consumer wanted to buy at a low price, but the middleman wanted to sell at a high one, and as a holder of warrants or a buyer of warrants he competed with both. The control of the market within the limits fixed by supply and demand fell into his hands and the supply or demand for iron could be increased or diminished by him because he could increase or diminish the supply of iron at any time by withholding or offering warrant iron.

It may be objected that the merchant could not really alter the price of iron because that is fixed by the law of supply and demand which only takes actuality into account, that is, the actual quantity of iron available and the actual demand for iron over a period rule the price. But it is this very power of increasing the actual quantity available by offering warrant iron or of decreasing that quantity by buying iron to put into store that enables the warrant holder to influence the market. It is only in times of great market movements, of exceptionally good trade, or of endeavours to "corner" the market that this powerful weapon of the warrant holder has been used to its full extent, but in ordinary times it is employed to influence the market within the legitimate range of prices. There are always limits within which a buyer will not hesitate to buy or a seller hesitate to sell. For instance, if the price of iron without any artificial influence were 50s. per ton, and if by the artificial influence of warrants the price were raised to 51s. or lowered to 49s. not a single genuine transaction would be stopped. In this case the margin for negotiation is 2s. per ton, but in some cases with high prices and good trade this margin may be 10s. or even 15s.

The effect of the creation of warrants was to import

into the trade a very convenient gambling counter which still further confused the issue between maker and consumer of iron. The dealings in warrants soon became quite disproportionate to the number in existence, and iron became a great medium for speculation. Men who had never seen a "pig" in their lives and would not have recognised one if they had met it in the street, bought and sold thousands of tons for which they had neither need nor use. The result was that all market movements were exaggerated. If the opinion was that prices would go up everyone rushed in to buy, and prices were sent up much higher than they otherwise would have gone, and if the opinion was that prices would go down everyone sold and prices fell beyond reason. The sole interest of the speculators is to have many ups and downs in the market, many changes, whereas for the genuine trader a steady market with few changes is the best.

The great centre of all this trade and speculation is the Glasgow Iron Market, which is carried on by members of the Scotch Pig Iron Trade Association and under its rules. The market itself is held twice daily from eleven to twelve and two to three o'clock in a corner of the Exchange, the "Ring" being a number of chairs set in a circle, upon which the members sit or behind which they stand. A photograph of the market in session, taken by kind permission of the Association, is given on page 82. The sitting is closed on the stroke of the hour by the ringing of a bell and the last offer and bid fix the official prices of buyers and sellers which are immediately posted up. When no bid or offer has been made the Secretary of the Association fixes the prices. At the end of the morning sitting the secretary fixes the settlement price for all transactions due for completion that day and such completion must be made by one o'clock. It will be easily seen that this system



CLARENCE IRON WORKS, WHERE SIR LOWTHIAN BELL'S EXPERIMENTS WERE MADE

may be abused. If a member wishes to have a low or a high price quoted in the official list without committing himself to a transaction he may call out a low offer or high bid just on the stroke of the hour, giving no one a chance of accepting it before the bell rings. His bid, or offer, fixes the buyer's or seller's price though no business has been done at it.

The temptation to members of the ring to manipulate the market by various devices could not well be resisted, and at last the ironmasters of Scotland came to the conclusion that the existence of the warrant store did not conduce to their interests, and they therefore declined to continue sending their iron into it. The store was therefore gradually depleted over the years 1900 to 1907, and now only 1,000 tons remain, the warrants for which have probably been lost.

The market in Scotch warrants has consequently ceased to exist, but there remains the store of Cleveland iron on the Tees, and this has taken the place of the Scotch in the speculative market. The position of the works in Cleveland differs from that in Scotland by the principal ones being on tide-water in the Tees, and in order to put the stores into the same position as the works as regards delivery, they also are on tide-water. The Cleveland warrant stores were not established for the same reason as the Scotch ones were. In the great boom years of 1872 and 1873 the demand for iron caused the warrant stores in Scotland to be almost emptied and the speculative market was hampered for want of the necessary counters in the form of warrants to gamble with. The "bears" were in constant dread of being "cornered" because it was not difficult to buy up all the warrants and, in order to increase the supply of these, attention was turned to Tees Side, where an increasing quantity of iron was being made. First the Railway Company opened a store in Middlesbrough

and then a private limited company was formed, but the warrants of these companies did not meet with ready acceptance. It was not until 1876 that the warrant store in Middlesbrough became firmly established, when Messrs. Connal & Co., Ltd., the proprietors of the Stores in Scotland, came to Tees Side. The quantity in the store has fluctuated very greatly, being once reduced to 7,000 tons and now standing at well over half a million tons. There are two places at which the iron is stocked, one at Middlesbrough, to which any of the works can send iron, and one at South Bank, near the Cleveland and Clay Lane works, to which iron from these works only can be sent. As the cost of sending iron to the Middlesbrough store is considerable, varying from 9d. to 1s. 6d. per ton, and as the works at South Bank can send their iron in without any cost to the store there, the tendency is for the store at South Bank to increase and for iron from all the other works to go into consumption. At one time only No. 3 iron was stored at Middlesbrough, and the Glasgow market accepted warrants for all brands classed as G.M.B. When the store was nearly exhausted some years ago the Glasgow market agreed to accept warrants for what they called "standard" iron, in order to provide the necessary counters for speculation. "Standard" iron was defined as certain brands of iron which included Lincolnshire, Northamptonshire and even American makes, and iron with a certain analysis with fixed differences for different qualities. But as anyone buying "Standard" iron did not know what quality of iron he would receive nor where delivery would be given the market in these warrants practically died out. This result shows that it is impossible to gamble in industrial things without a substratum of real trade. Gambling may be the froth or scum, but there must be good liquor or good metal underneath. It is because

no one bought standard warrants for consumption of the iron they represented that no business is done in them.

The market position is a distinctly humiliating one for the Cleveland ironmaster, who goes to his Exchange twice daily to find out what price has been fixed for his iron in Glasgow by somebody who has bought 500 tons of warrant iron which he does not want from somebody who has not got it.

For some years the hematite iron-makers of Cleveland also used the warrant stores, but they, like the Scotch makers, found it not to their advantage and they discontinued sending in their iron. The hematite makers of Cumberland still use it, and their warrants are quoted in Glasgow, though the actual transactions are not numerous.

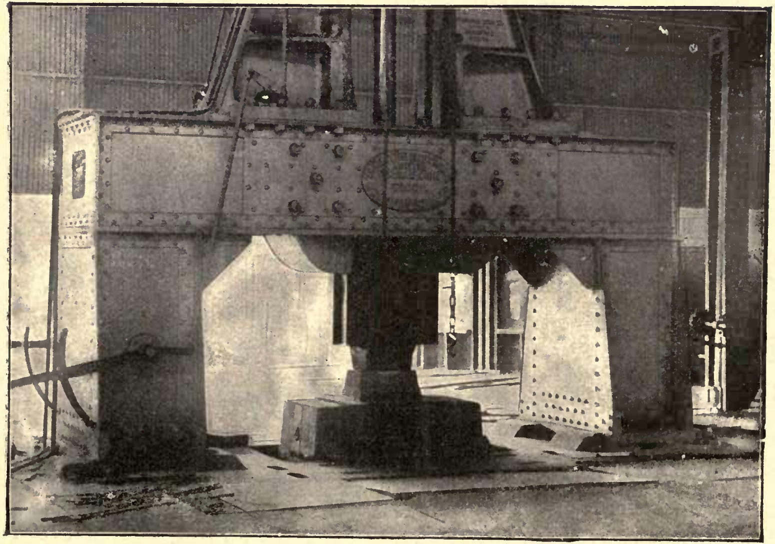
The question of warrant stores cannot be dismissed without pointing out that they have at times and under certain circumstances served a useful purpose. They have enabled the manufacture of pig iron to go on in bad times when works would have stopped if accumulating stocks could not have been disposed of or pawned. It may fairly be said in reply to this that such works were being carried on with too little floating capital, and that is true, but in a new industry it is not always possible to obtain sufficient capital to tide over a time of depression. Then in the case of consumers, sometimes makers are not willing to make contracts a long time ahead, and if, say, a pipe-maker makes a contract to deliver pipes, as he sometimes has to do, over two or three years, he cannot cover his sale by buying his pig iron from the producer. But he can buy warrants up to the full quantity of his requirements, and the only extra cost he is put to is the cost of "carrying" them until he wants the iron, and this he can provide for in his quotation for the pipes. One result of the control of the Cleveland market in Glasgow has been that contracts

are now made for shorter periods than formerly, six months or so forward being a usual limit. In the early days in Cleveland it was quite usual to make heavy contracts for twelve months and even eighteen months. The Glasgow merchants point out that it is not fair to blame their market for unsatisfactory prices, because the warrant market has frequently been the means of raising and maintaining prices, but this is only another way of saying that the consumer as well as the producer has contributed to their maintenance. It must not be supposed that the Glasgow market has no legitimate reason for existence, all that has been said is in criticism of the use of iron as a medium for speculation and market manipulations. The enormous increase in the use of iron in modern times has been brought about by two factors, cheapness and quality. When iron was £20 a ton it was too dear to use for most of the purposes it serves to-day, when it was reduced to £2 it found new outlets in every direction. So if by interposing expensive methods of trade between producer and consumer its value is raised the demand for it will not be so great. There is a legitimate office for the merchant to fill in bringing maker and user, now far apart, into contact, but where no such office exists the middleman is but a parasite on trade. This legitimate office is well filled by many of the large merchant firms of Glasgow and Middlesbrough, whose branches and agents are found in every part of the world, and whose integrity and business ability are recognised wherever iron is bought and sold.

A "CORNER" IN WARRANTS

In connection with the warrant market the famous corner in iron in 1905 may be briefly referred to, and this will give a very good idea of what is meant by illegitimate trading.

In the summer of 1904 the stock of Cleveland iron in the warrant store was comparatively low, and a merchant firm in Middlesbrough thought there was an opportunity of "cornering" the "bears." Accordingly they commenced to buy warrants at three months in Glasgow. The operation was at first not suspected by the market. As the iron became due the operators "carried" the warrants instead of taking delivery. The price in the early part of October was 43s. per ton, and the stock was 94,889 tons. As the buying continued the price of warrants rose steadily and the stock of iron increased, as more money could be obtained for iron in the store than from consumers. The demand for consumption fell off, and when the price for warrants at three months rose to 1s. 6d. per ton above the prompt price for makers' iron some of the makers sold warrants at three months and arranged to store the iron before the warrants became due. When the endeavour to "corner" the market became evident in the early part of 1905 the operators had succeeded in buying two or three or more times the quantity of iron in store at that time. The store had increased by 20,000 tons in October, 34,000 tons in November, 41,000 tons in December, 47,000 tons in January and 40,000 tons in February, by which time there were 276,725 tons in stock. The price had risen from 43s. in October to 46s. in November, 51s. in December, and after a set-back in January and February, reached 52s. in April. The fight now began in earnest. The operators refused to "carry" purchases beyond the 19th of May, and it soon became evident that that date was fixed for closing the operation. The price mounted up daily and frantic efforts were made by the "bears" to get iron into the store to implement their contracts. All genuine trade was at a standstill. Keels to carry the iron to the store became unobtainable, the railway sidings were blocked



A LARGE HAMMER

Reproduced by permission of Messrs. Jonas and Colver, Ltd.

with traffic to the store, iron was even brought back from Scotland to be put in. In March the store increased by 59,000 tons, in April by 62,000 tons, and in the first nineteen days of May by no less than 81,000 tons, so that on the settlement day there were 478,009 tons in store. The operators had to take over 460,000 tons of warrants and they received differences, which from the commencement of the operation amounted to about 12s. per ton, on a large quantity which the "bears" failed to deliver. The settlement price on May 19th was 54s. 9d. per ton, and at the next market warrants were offered at 46s. per ton. The corner had succeeded, it had compelled the "bears" to pay large sums to the operators as differences for iron they had sold and could not deliver. But it was a barren victory. The operators had received a large sum of money but they had to "carry the baby"—the whole stock of warrants. The sore "bears" naturally declined to do anything towards relieving them, and in order to get rid of the warrants they had to sacrifice the money they had received. They ultimately got out without any loss, but practically without any profit. For the time being the whole trade was disorganised, orders for iron were lost, markets were thrown into confusion, legitimate business was neglected everybody was worked to distraction and all because one set of men had sold what they did not possess and another had bought what they did not want. The operation resulted in no increase of wealth, it merely transferred a certain amount of money from one set of pockets to another, in fact, it differed in its effect in no single point from pure gambling.

CHAPTER XIII

PROTECTIVE POLICIES AND COMBINATIONS OF MANUFACTURERS

It has been suggested that the change in the relative position of the three great iron producing countries of the United States, Germany, and Great Britain, has been influenced if not brought about by the policy of protecting the home market by import duties which is pursued by the two former. Without entering into any argument upon what has unfortunately become a political question, a few facts bearing on it may be mentioned. With regard to Germany it is sufficient to repeat what has already been said, that the development of her enormous resources of cheap ore in Elsass-Lothringen is due to the basic process of steel-making. Without that process this ore would have been of little use; with it steel can be made as cheaply if not more so than in any other country. No one can say whether this great field of ore would have been developed more or less quickly if the home market for iron had not been protected; but that it would have been developed is absolutely certain—men do not find gold in a mine and leave it there.

With regard to America there are two facts to be mentioned. First, it was a physical impossibility for Great Britain to supply America with the increased quantity she required, even if America had been willing to buy from us rather than develop her own resources. Second, the cost of delivering British iron even to the Eastern States in competition with local iron is in ordinary times prohibitive, even if no import duty is levied.

Iron is made in the Southern States at about the same cost as in Middlesbrough, and at the Mahoning and Shenango Valley furnaces at a few shillings more. Is it to be imagined that the Americans would be so foolish as to refrain from making iron at these costs and pay us 10s. to £1 per ton more for our iron which is no better than theirs? America, in times of scarcity of iron, draws upon Europe to supplement her own supplies and, with a duty, she comes later than she would without one. But her own works have been built and her output increased because she wants the iron and can make it more cheaply than we can deliver it, duty or no duty.

The whole question of competition in the iron and steel trades is one which cannot be adequately dealt with in the space available here, but the outlines of it may be generally indicated. Dealing first with the outside markets it is to be borne in mind that there is no such thing as national competition, though national pride may enter into the contest between individual firms of different nationalities. The competition for, say, an Australian or South American order is not between Germany and England and America, but between various manufacturers, some of whom are German, and some English, and some American. Each of these manufacturers tries to put himself into the best possible position for taking the order, and it is the methods which he is able to adopt to this end which distinguish the nationalities. The competition which each manufacturer has to consider is of two kinds. There is the competition of firms working under the same conditions and in the same country, probably paying the same wages and using the same raw material in the manufacture as himself, and there is the competition of firms working under different conditions, helped or hindered by governmental rules and imposts or the

absence of them, in another country. The one he calls home, the other foreign competition. In a perfectly untrammelled, unorganised condition of the producers he would be unable to eliminate any of this competition and would have to quote a price that would leave him the smallest amount of profit that he was willing to take, or, if he were badly off for orders to keep his works going, a price which at the worst would leave him a loss, but a smaller loss than he would suffer if he allowed his works to stand. Supposing that the works in all the countries producing the particular goods were capable of turning out more than there was a demand for, the price under open competition would be kept at about the average cost of production, the most favourably placed works making a profit, the least favourably placed making a loss and in time being obliged to stop. But if the manufacturer can arrange with all his competitors to decide beforehand which of them shall take the order, he can ensure a better price being paid by the buyer, and therefore one which is higher than some of the manufacturers would have been willing to accept. This is the arrangement to which the makers of rails have come who are members of the International Rail Association, which comprises all the large rail firms in the world. When a large rail order is in the market the " Rail Pool," as it is called, holds a preliminary competition for the order and takes tenders for the right to quote the lowest price. The Pool fixes the price to be quoted, and the firm offering the rails to the pool at the lowest price is told to quote that price, all the unsuccessful firms being instructed to refrain from competing or to quote a higher price. The firm which gets the order has to pay into the Pool the difference between the price it quoted to the Pool and the price it receives. These differences are divided

up among the members of the Pool so that a member receives for an order the price he quoted to the Pool plus his share of the surplus. There are other qualifying rules as to markets in different countries, but this is broadly the principle upon which the Association is based.

This arrangement eliminates all competition, and the only point that the members have to consider is that the prices quoted shall not be such as to induce outside firms to take up the manufacture of rails.

If, however, such a complete combination cannot be effected the manufacturer may be able to make an arrangement with the other manufacturers in his own country to eliminate all home competition. It is because it is much easier to combine makers of an article in one country than in many countries that such combinations have become so numerous as to give the impression that competition is national and not individual. The German syndicates in the iron and steel trades are examples of combinations for the elimination of home competition, but in no case do they provide for meeting foreign competition. Only when they embrace all the makers of the particular goods they represent can they be completely successful; when only a portion of the makers are combined they can only be successful where they have distinct advantages, say a near market, over the rest of the makers. The present *Stahlwerks Verband* and the Pig iron syndicates, which were abandoned at the end of 1908, practically included all the makers. The former deals with nearly all the raw and semi-finished steel made in Germany. This is divided into two classes, A products, which comprise the heavy materials such as semi-finished steel, rails and rolled railway material and shapes, and B products, which comprise merchant bars,

flats, rounds, hoops, wire, wire-rods, plates, sheets, castings, forgings, axles, wheels, etc. The management is in the hands of a committee representing the various works who meet monthly. The committee buys from the works and sells A products direct to the consumer except for very small orders and special qualities of steel. The B products are bought by the committee and sold to subsidiary syndicates under stringent conditions. Disputes are settled by arbitration. When the home trade is insufficient to absorb the output the syndicate is, as our American friends would say, " up against " the competition of makers in other countries, and in order to obtain orders for the surplus unmarketable at home a heavy concession in price has to be made. To cover this the syndicate gives a bonus to the manufacturers who are allotted foreign orders, varying it according to the state of the market. This bonus comes out of the profit of the home orders.

The United States Steel Corporation is an example of another form of combination for the elimination of home competition. It is the least effective form because it includes only a portion of the production. The Corporation was formed by the amalgamation of a number of large firms commanding a large proportion of the trade. It was necessarily handicapped in capital to start with, as very large sums had to be paid for some of the works to induce the owners to part with them. It possesses large resources in raw materials, and in that respect has a great advantage over most of the firms outside it. In fact, its power and influence on the trade is based on its command of raw material which enables it to manufacture at a lower cost than its competitors. It cannot dictate to the trade but it can exercise powerful coercion. Similar Combinations to this in England are the Salt Union and the United

Alkali Company. Combinations of manufacturers of iron are by no means confined to Germany and America. Many branches of the iron and steel trades in Great Britain are controlled by syndicates. Quite recently the following paragraph appeared in the *Yorkshire Post* (November 25th, 1910):

"An Edinburgh correspondent reports that, after protracted negotiations, the Scottish malleable iron-makers have concluded an agreement for the regulation of the output. Makers are to be allocated a certain output, both for home trade and export, a payment to be made into a pool in the event of the allotment being exceeded, and compensation being received therefrom if the output falls below. As a preliminary step, export prices have been raised by 5s. per ton, but still leaving them from 7s. 6d. to 17s. 6d. per ton under the official minimum prices quoted at home."

From this it will be seen that the usual accompaniment of the formation of a syndicate, a rise in prices, is not absent, but the most striking point is the evidence of a lower price being charged to the foreigner than to the home consumer for the same goods.

The country which suffers most from—or whose trade most enjoys the advantage of—syndicates is Germany. If the coal and ore in the ground are regarded as the starting-point of the trade and the highly-finished and complete product of iron or steel as the end, no less than seventy-five to eighty syndicates are concerned in the manufacture and sale of the articles of this one trade alone. The cause of this may be that Germany has gone farther on the road of the organisation of its industries than other countries, or it may be that there is something in the character or training of Germans which makes these syndicates more necessary for them than for others. Their habits of obedience drilled into

them during their military training certainly render them less self-reliant individually than Britons or Americans are, and they work more effectively in combination and in mass. Perhaps it is only another form of the controversy of Line *v.* Column, and if that is so the Line is bound to win, but the conditions are not quite the same.

The first syndicate formed was that of coal, which began in Westphalia in 1878. The origin of it was the same as that of so many others of its kind, unremunerative prices. It gradually developed and ultimately took the form it now has in 1893, being renewed from time to time. This syndicate takes the form of a company of which the constituent mines hold the shares. The mines bind themselves to sell all their saleable output to the company except that for local consumption. The syndicate can sell coal from other mines by arrangement. The market is divided into districts, and separate selling offices in each district regulate the retail prices. In order to prevent outside competition the syndicate compelled customers to pay a fine of sixpence per ton for all coal not bought from it, but in 1907, when the syndicate could not supply all the demand, this rule was relaxed. Prices were fixed for a year from April to April, but this led to great difficulties in a falling market and has been modified, but the consumer has no option and must take what the syndicate will give him. The result has been that the large iron and steel works rather than remain at the mercy of the coal syndicate bought collieries for their own supply, reserving the coal required for their own use and sharing in the profits of the syndicates' sales.

Pig iron, intermediate between the coal and the finished steel, has been ruled by syndicates which, until they came to an end in 1908, worked together. These

were the Düsseldorf syndicate for Rhenish Westphalia; the Luxemburg; the Siegen; and the Upper Silesian Syndicates. There were several reasons for the break-up of these combinations. An important one was the opposition of the Kraft works at Stettin, which draw all their supplies of raw material from abroad, and which refused to join. Another was the opposition of the great merchants who found themselves being pushed out of the business by the directors of the syndicate who tried to deal direct with consumers. It should be explained that in Germany the greater part of the trade in iron passes through the hands of four great firms of merchants, most of whom are also interested in certain of the large works. When it was found impossible to renew the syndicates in the old form an arrangement was made in Westphalia called a "Verkaufs-Vereinigung," or Selling Association, by which the make of iron and the sale of it is controlled. An endeavour was made to include Luxemburg in this arrangement, but it failed, and the whole output of iron in that district has been bought by the merchants in question for a period. The main idea with these new arrangements is to keep out foreign, *i.e.*, British iron, and to preserve the German market for the German maker, exporting any surplus output at any price it will fetch.

The conflicting interests of the various districts, the opposing interests of various firms, the great difference in the qualities of the product and other reasons render it improbable that any permanent combination of the makers of pig iron can be brought about. But the syndicate which has been the most successful in Germany is that of the steel works, which has already been referred to. An interesting article appeared in the *Iron and Coal Trades Review* of August 26, 1910, by its Düsseldorf correspondent upon the future of the German

steel industry. The writer referred to the way in which the syndicates affect the trade. He showed how, starting at the coal syndicate, collieries were amalgamated with steel works so as to avoid the operations of the syndicate, how steel works making raw steel had been forced on by the syndicate to make more highly-finished steel, and how the tendency of the syndicate was to force these into making still more highly-finished goods so that they could make these goods freely without the intervention of the syndicate. It would appear from this that the syndicate is losing its importance to the large combined works, that is the works which, having their own coal, manufacture highly-finished steel from their own raw material. If these works refuse to join in a renewal of the syndicate in 1912 there will be small chance of it being carried out, and if it is abandoned a period of free competition will set in during which the worst situated or worst managed works will probably go to the wall. This brings out one important feature of syndication, viz., that it props up the weakest firms and puts them on the same level as the strongest in the market. The strongest and best firms are handicapped by being tied down to the same selling conditions as the feeblest, and can only mend their position as the German firms are doing by taking up higher branches of the trade—and waiting for the end of the syndicate.

The tendency of all syndicates is to try to make their control more effective. The perfect syndicate is that which without fear of interference can dictate its own terms to the trade. It aims at supreme power and is never quite satisfied with less. It is this striving after completeness and autocracy which led to the suggestion which Mr. Gary, the able President of the American Steel Corporation, placed before the members

and guests of the American Iron and Steel Institute at their recent meeting in New York. Mr. Gary suggested a combination which should embrace all the makers of iron and steel in the world and control all the output. The argument was that competition between makers of iron is out of date and does not increase the demand for iron. It should be eliminated by agreement among the makers to fix prices. Open competition has no other result than to compel some makers to sell their iron at a loss. The making of iron is not a philanthropic duty, and the first necessity is that the maker should receive his just reward. It is not fair that a user of iron should pay less for it than it has cost, and the makers should not allow him to do so. Both the makers and users of iron are equally interested in the trade, and the users may safely leave their interests in the hands of the makers because it is not in the makers' interests to charge the users an exorbitant price, since that would reduce the consumption. It is a great conception arising naturally out of such organisations as the Rail Pool, and the *Stahlwerksverband*, but the difficulties which would arise in attempting to carry it out seem too great to be overcome. The difficulties which the *Stahlwerksverband* is meeting with are so great that it is doubtful if it will be possible to renew it when it comes to an end in 1912. The difficulties of a world-wide *Stahlwerksverband* would be immeasurably greater.

With regard to Mr. Gary's suggestion that the interest of the buyer of steel may safely be left with the seller, if the millenium were close at hand and casting its shadow before it one might conjure up a little faith in the possibility of the lion and the lamb lying down together without any unfortunate result. But until human nature alters a good deal it is hard to believe that when two men bargain together and one has all

the advantage a "square deal" will result. That can only arise when both dealers are free agents and on even terms. Mr. Gary himself may have high ideals and be able to treat a "tied house" fairly and justly, but it is not possible for him to guarantee that all the men with whom he would be associated in Europe and America would do the same. It is perhaps only necessary to turn to the legislative enactments of the Government under which Mr. Gary lives to find the strongest condemnation from the national point of view of his suggestion. The Anti-Trust laws of the United States are the outcome of the tyranny exercised by combinations of manufacturers or distributors over the consumers. Can it be said that a combination of world-wide extent possessing absolute power would deal with its customers with more fairness, impartiality and strict justice than the smaller trusts confined to the United States and having foreign competition to meet have done?

The question of syndicates, their advantages and disadvantages, is worth looking at from different standpoints. First naturally comes that of the produce s who combine. They are engaged in an industry which employs a large number of men whose daily bread as well as whose higher interests depends upon it. It would appear to be not only justifiable but highly desirable that this industry should be protected as far as that can be done from those vicissitudes of trade which bring distress and loss to those engaged in it. This can only be done by refusing to sell at prices which are unremunerative, and only by an agreement among all the makers can such a course be effective. Thus the interests of those engaged in the trade is the real reason for combination. The question therefore is, does combination really and truly advance the interests of those engaged in the trade? There is not much doubt that,

in its first effect, it does. Take any well-known case, say the Rail Makers' Association, where the price of rails has been maintained at a remunerative figure in spite of a potential output largely in excess of the demand, and it must be acknowledged that without the syndicate the price of rails would have been reduced to a ruinous figure for all concerned in the manufacture. But although the law of self-preservation is as cruel in trade as it is in life the effects of suspending it or interfering with its operation are not always immediately visible, and results quite unlooked-for may occur in the one province as they have in the other. It is well, therefore, while acknowledging the immediate benefit of syndication to the manufacturer to consider some of the results of it which are longer in appearing. It is one of the recognised effects of a high return for money invested in an industry that capital naturally flows in its direction with the result that in time the return on the investment is lowered until it comes below that of similar investments and capital ceases to flow towards it. If, therefore, profits in the iron trade are kept abnormally high by prices being artificially maintained through syndication, capital should be attracted towards iron-making. When the position of Germany in regard to iron and steel is looked at impartially it will be recognised that this is what has happened. If syndication had taken the form of an amalgamation of interests, as in the case of the Steel Corporation in America, there would have been some inducement to be cautious in making and marketing more material than was required, but in the case of the pig iron syndicates and the Stahlwerksverband of Germany, every separate firm composing these combinations was desirous of increasing its own individual output so as to get a larger share of the profits which the prices gave than it was

receiving. The consequence has been that new plant has been put down and the output increased wherever that has been possible and without any regard to the possibility of marketing the goods. At the present time the output of iron and steel is increasing steadily, and on the expiry of the Stahlwerksverband in 1912 the impossibility of satisfying the claims for larger allotments will probably result in the break-up of the combination. If that happens, prices will fall heavily, the return on capital will come down and extensions will cease because the trade will no longer attract investors.

It would, therefore, appear to be imperative in the manufacturers' own interests that syndications should not result in abnormal prosperity which will exist only for a time and give place to losses and disasters, but that the prices fixed should only be such as will give profits equal to but not larger than are obtainable in other similar industries. The policy should be a protective one to prevent losses, to maintain the trade, to keep prices steady, not one to make large profits regardless of others or to extend the trade at all hazards.

The point of view of the consumer with regard to syndicates is naturally the opposite of that of the manufacturer. To him they are unmitigated evils which prevent him making a bargain and securing more profit for himself. And there can be no question that in the main he is right. He has to take all the risk of the rise and fall of the market in the goods he sells, but it is probably all rise and no fall in what he buys. His only remedy is to syndicate for himself and put up his own price to his buyer, and so syndication goes on until the actual consumer is reached—and even he syndicates by joining a co-operative society, which is merely a syndicate of buyers. But if a syndicate is far-sighted

and looks to its own interest in the future as well as in the present it will not squeeze its clients so hard as to drive them out of the trade, and it may even make itself welcome to them by steadying markets and making trade more regular and reliable.

There is another point of view which, while embracing both that of the seller and buyer, takes in a wider horizon. This is the view from the standpoint of the nation or even of the world. Buyer and seller are but parts of the machinery which supplies the material wants of the whole people. All that is necessary from this standpoint is to hold the balance even between the various interests, and any schemes which give an unfair advantage to any interest, be it of seller or buyer, producer or consumer, maker or user, must in the interests of the whole community be discouraged. Therefore the United States Government prosecutes the Oil Trust because it deals unfairly with the consumers of oil, and makes laws to prevent the control of trade being used against the interests of the people as a whole. From the national point of view, all combinations are endeavours to benefit a few people at the expense of all the rest, and that cannot be in the national interest. More especially are such combinations harmful when they sell their products abroad at a lower price than is charged to the home consumer. Supposing that goods are exported which have cost £1,000, which in labour would be represented by 4,000 days' work, but instead of being sold for £1,000 they are sold for only £900. The goods which have to be imported to pay this £900 will only represent 3,600 days' work, so that the nation spends 4,000 days' labour in exchange for 3,600 days' labour of the foreigner. Not only that, but if a home customer wants the same goods and is charged £1,100 he has to expend the value of 4,400 days' labour to pay

for them, so that the buyer at home spends 800 days' more labour for the same goods than the foreigner. As labour is a national asset this is a waste of national resources.

It is not safe to prophesy even where there are few possibilities, and on such an intricate subject as syndicates it would be foolish to attempt to forecast the future. One or two considerations may, however, be mentioned. When the private interests of a firm have clashed with those of the public at large it has never happened that the public interests have been alone considered, in fact, from the firm's point of view, it would be traitorous to consider any other than its own. It seems to follow from this that syndicates will not only survive but become more general. But as the United States Government has found it necessary to legislate for the protection of the public against Trusts it will probably be necessary, as Trusts become more numerous, for other Governments to do the same, and this could only result in popular condemnation of syndicates and all their ways. Thus there would arise constant antagonism between the State and the syndicates which would probably have no definite result. The State, however, would be greatly handicapped in any attempt to prevent unfair advantage being taken by any combination of manufacturers unless the power of the combination were pushed to very extreme limits.

APPENDIX

MAKE OF PIG IRON IN ENGLISH TONS

Year.	Great Britain.	Germany.	U.S. America.	France.	Russia.	Austria-Hungary.	Belgium.	Estimated Total Production of the World.
1500	6,000	5,000		12,000				60,000
1700	12,000	10,000		22,000				104,000
1740	17,350	(Prussia	1,000	26,000				157,000
1788	68,300	only until						
		1874)						
1796	125,079	*30,000	*30,000	*40,000(	1790)*			278,000
1806	258,206	*40,000	*40,000	*60,000(	1800)*			460,000
1810	250,000	46,000	53,900	85,000				616,000
1818	325,000			114,000				
1820	368,000	90,000	110,000	140,000				1,010,000
1823	452,000							
1824				195,000				
1825	581,367			196,000				
1826				203,000				
1827	690,500			213,000				
1828	703,000		130,000	218,000				
1829			142,000	214,000				
1830	678,417	120,000	165,000	223,000		72,000	52,000	1,585,000
1831			191,556	221,000				
1832			200,000	222,000				
1833	700,000		225,000	233,000				
1834				265,000				
1835	1,000,000		270,000	290,000		91,000		
1836	1,200,000			304,000			118,000	
1837		99,000						

* The starred figures are all for 1790 and 1800.

MAKE OF PIG IRON IN ENGLISH TONS (*Continued*)

Year.	Great Britain.	Germany.	U.S. America.	France.	Russia.	Austria-Hungary.	Belgium.	Estimated Total Production of the World.
1838		93,000					74,000	
1839	1,347,790	106,000	230,000				74,000	
1840	1,248,871	111,000	315,000	350,000				2,680,000
1841	1,500,000	108,000						
1842	1,200,000	101,000	215,000				52,000	
1843	1,200,000	101,000						
1844	1,400,000	99,000						
1845	1,512,500	110,000	486,000					
1846		117,000	765,000					
1847	1,999,508	138,000	800,000			166,000		
1848		128,000				166,000		
1849		117,000						
1850	2,300,000	134,000	564,755	405,000	250,000	161,000	144,000	4,422,000
1851		148,000						
1852	2,701,000	167,000						
1853		210,000						
1854	3,069,838	261,533	657,337					
1855	3,218,154	301,387	700,159					
1856	3,586,377	363,881	788,515					
1857	3,659,477	397,274	712,640					
1858	3,456,064	413,343	629,548					
1859	3,712,904	396,892	750,560	746,700				
1860	3,826,752	395,741	821,223	785,328		312,000	319,943	7,180,000
1861	3,712,390	449,339	653,164	816,380				

MAKE OF PIG IRON IN ENGLISH TONS (*Continued*)

Year.	Great Britain.	Germany.	U.S. America.	France.	Russia.	Austria-Hungary.	Belgium.	Estimated Total Production of the World.
1862	3,943,469	526,077	703,270	913,908				
1863	4,510,040	637,679	846,075	919,157				
1864	3,767,951	705,967	1,013,837	1,017,828				
1865	4,819,254	771,903	831,770	974,336			463,331	9,292,000
1866	4,523,897	803,552	1,206,190	977,031		281,125		
1867	4,761,023	987,668	1,303,123	917,187		314,850	416,387	
1868	4,970,206	1,053,260	1,431,250	920,103		388,838	428,871	
1869	5,555,757	1,180,579	1,711,287	1,602,807		398,684	525,880	
1870	5,963,515	1,155,591	1,665,178	909,250	359,989	396,588	556,306	11,616,000
1871	6,627,179	1,297,940	1,796,793	846,063	384,776	417,899	599,608	12,565,000
1872	6,741,929	1,457,835	2,548,712	1,198,608	399,273	452,365	646,195	14,445,000
1873	6,566,451	1,573,902	2,560,962	1,345,158	417,814	526,065	597,780	14,693,000
1874	5,991,408	1,817,182	2,401,261	1,400,827	419,167	486,840	524,375	13,407,000
1875	6,365,462	1,997,335	2,023,733	1,394,026	470,610	447,394	531,937	13,708,000
1876	6,555,997	1,876,155	1,868,967	1,430,161	486,771	394,101	482,760	13,671,000
1877	6,608,664	1,902,199	2,006,585	1,498,224	440,669	402,540	463,056	13,627,000
1878	6,381,051	2,114,073	2,301,215	1,484,425	458,835	417,548	485,749	14,296,000
1879	6,009,434	2,100,294	2,741,853	1,323,520	476,962	397,776	441,288	14,145,000
1880	7,749,233	2,686,269	3,835,191	1,698,043	441,510	456,936	598,480	18,254,285
1881	8,377,364	2,868,064	4,144,253	1,856,557	462,627	535,054	614,868	19,727,776
1882	8,493,287	3,327,400	4,623,323	2,006,860	555,773	602,070	715,457	21,122,152
1883	8,490,224	3,415,084	4 595,510	2,036,743	376,236	687,819	771,058	20,744,397
1884	7,528,966	3,543,742	4,097,868	1,841,977	502,075	722,748	738,953	19,822,250
1885	7,297,295	3,629,192	4,044,526	1,604,894	519,828	703,497	701,616	19,479,287

MAKE OF PIG IRON IN ENGLISH TONS (*Continued*)

Year.	Great Britain.	Germany.	U.S. America.	France.	Russia.	Austria-Hungary.	Belgium.	Estimated Total Production of the World.
1886	6,87 0,665	3,472,924	5,683,329	1,492,621	524,330	708,609	690,595	25,453,803
1887	7,441,927	3,960,347	6,147,148	1,542,862	603,499	693,373	743,844	22,614,382
1888	7,898,634	4,268,912	6,489,738	1,656,763	657,190	777,715	813,789	23,636,584
1889	8,245,336	4,453,094	7,603,642	1,706,576	729,254	842,295	819,081	25,618,847
1890	7,875,130	4,584,873	9,202,703	1,931,204	908,998	950,134	775,392	27,194,294
1891	7,228,496	4,567,910	8,279,870	1,867,420	988,876	907,285	673,322	25,815,787
1892	6,709,255	4,859,476	9,457,000	2,024,763	905,089	925,433	741,371	26,435,319
1893	6,829,841	4,907,251	7,124,502	1,971,457	1,142,404	967,185	733,493	23,846,336
1894	7,427,342	5,295,062	6,657,388	2,037,023	1,292,026	1,037,865	805,667	25,647,379
1895	7,703,459	5,378,191	9,446,308	1,972,216	1,431,328	1,058,021	816,136	29,385,853
1896	8,659,681	6,271,924	8,623,127	2,302,584	1,604,069	1,112,153	933,050	30,520,043
1897	8,796,465	6,772,776	9,652,680	2,444,953	1,827,669	1,185,968	1,018,689	32,990,569
1898	8,609,719	7,197,263	11,773,934	2,485,192	2,205,888	1,266,071	964,280	35,843,677
1899	9,305,319	8,014,514	13,665,015	2,537,676	2,665,964	1,303,088	1,008,394	39,095,158
1900	8,959,691	8,385,960	13,734,860	2,671,426	2,849,898	1,291,228	997,553	39,557,076
1901	7,928,647	7,755,624	15,801,813	2,351,092	2,756,917	1,458,125	752,110	40,243,525
1902	8,679,535	8,395,172	17,821,307	2,366,988	2,555,981	1,313,915	1,052,323	43,854,214
1903	8,935,063	9,859,672	18,009,252	2,783,005	2,307,961	1,364,109	1,197,286	46,279,438
1904	8,693,650	9,944,354	16,497,033	2,952,406	2,931,283	1,401,509	1,267,263	44,701,624
1905	9,608,086	10,814,078	22,992,380	3,027,956	2,091,436	1,350,626	1,289,595	53,201,008
1906	10,183,860	12,276,059	25,307,191	3,266,609	2,312,882	1,661,832	1,408,555	58,231,728
1907	10,114,281	12,839,707	25,781,361	3,532,263	2,772,762	1,843,417	1,405,387	59,721,399
1908	9,056,851	11,626,922	15,936,018	3,337,588	2,756,416	1,846,370	1,187,385	47,601,731
1909	9,664,287	12,713,623	25,795,471	3,488,652	2,825,978	1,916,248	1,606,568	59,544,425
1910		14,559,670	27,298,545				1,775,015	64,000,000

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